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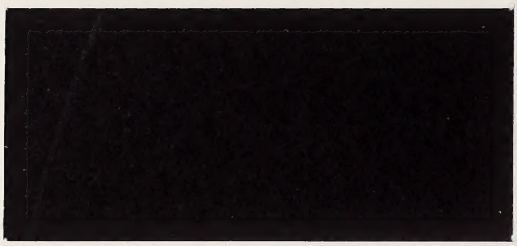
MONITORING OF BLACK FLY (DIPTERA: SIMULIIDAE) ABATEMENT PROGRAM ON THE ATHABASCA RIVER - 1983

POLLUTION CONTROL DIVISION

Alberta
ENVIRONMENT



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MONITORING OF BLACK FLY (DIPTERA: SIMULIIDAE) ABATEMENT PROGRAM ON THE ATHABASCA RIVER - 1983

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EXECUTIVE SUMMARY

In 1983, two methoxychlor treatments of the Athabasca River for larval black fly control were monitored by the Pesticide Chemicals Branch of Alberta Environment, Environmental Protection Services, Pollution Control Division.

Non-target benthic invertebrate populations were studied during the open water season to assess short term and long term effects caused by the methoxychlor treatments. Drift sampling (short term) showed a substantial increase (up to 1000 times) in the number of invertebrates collected in correlation with methoxychlor residue concentrations. On the other hand, bottom samples (long term) did not show immediate or long term changes because of the methoxychlor treatments.

Water samples were collected in the Fort McMurray area because of the large domestic and industrial water demand from the Athabasca River. Methoxychlor residue levels of up to 2.0 parts per billion were detected in Athabasca River water. Trace levels of methoxychlor were detected in the City of Fort McMurray raw water reservoir, but residues were not detected in the treated drinking water supply.

Sediment samples were collected from the Lake Athabasca Delta to determine whether methoxychlor was accumulating in this depositional area. No residues of methoxychlor or other pesticides were detected in the samples.

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Adult black fly data were compiled to assess the efficacy of the treatment program, and to compare the distribution of black flies within the endemic black fly problem area. The effect of river larviciding on adult black fly populations was evident when, in August, an untreated larval population emerged to create a severe attack on cattle in the northern section of the problem area. Throughout the summer, black flies were collected in low numbers in the southern part of the problem area around Grassland, and in relatively higher numbers in the northern section around Wandering River.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

The Pesticide Chemicals Branch of Alberta Environment, Environmental Protection Services, Pollution Control Division monitored a black fly (Diptera : Simuliidae) control program conducted along the Athabasca River in Northern Alberta during the open water season of 1983, as part of an on-going monitoring program. The control program was carried out by the County of Athabasca No. 12 to alleviate problems of black flies attacking cattle in the Grassland-Wandering River area (Figure 1), where large and intense infestations of black flies (primarily Simulium arcticum) occur during the summer months. The presence of this black fly species is one of the major factors which restricts expansion of livestock production in this area. The pesticide applied to the Athabasca River to control the larval stage of S. arcticum was methoxychlor, an organochlorine pesticide developed in the late 1940's (Anon, 1949). An extensive evaluation of methoxychlor as a black fly larvicide was conducted in the Athabasca River between 1974 and 1977 (Haufe, 1980; Haufe and Croome, 1980), and the current control and monitoring programs are, in large, based on that work.

The objectives of the 1983 study were:

1) to monitor the effect of methoxychlor on the non-target biota of the Athabasca River by determining whether population reductions occurred after treatment;
2) to determine the time of recovery by the non-target biota;
3) to monitor methoxychlor residues in Athabasca River water in the vicinity of Fort McMurray;
4) to determine the residue levels of methoxychlor and other pesticides in the Athabasca Delta area;
5) to assess the effect of the larval treatment program on populations of adult black flies in farming areas affected by the black fly control program.

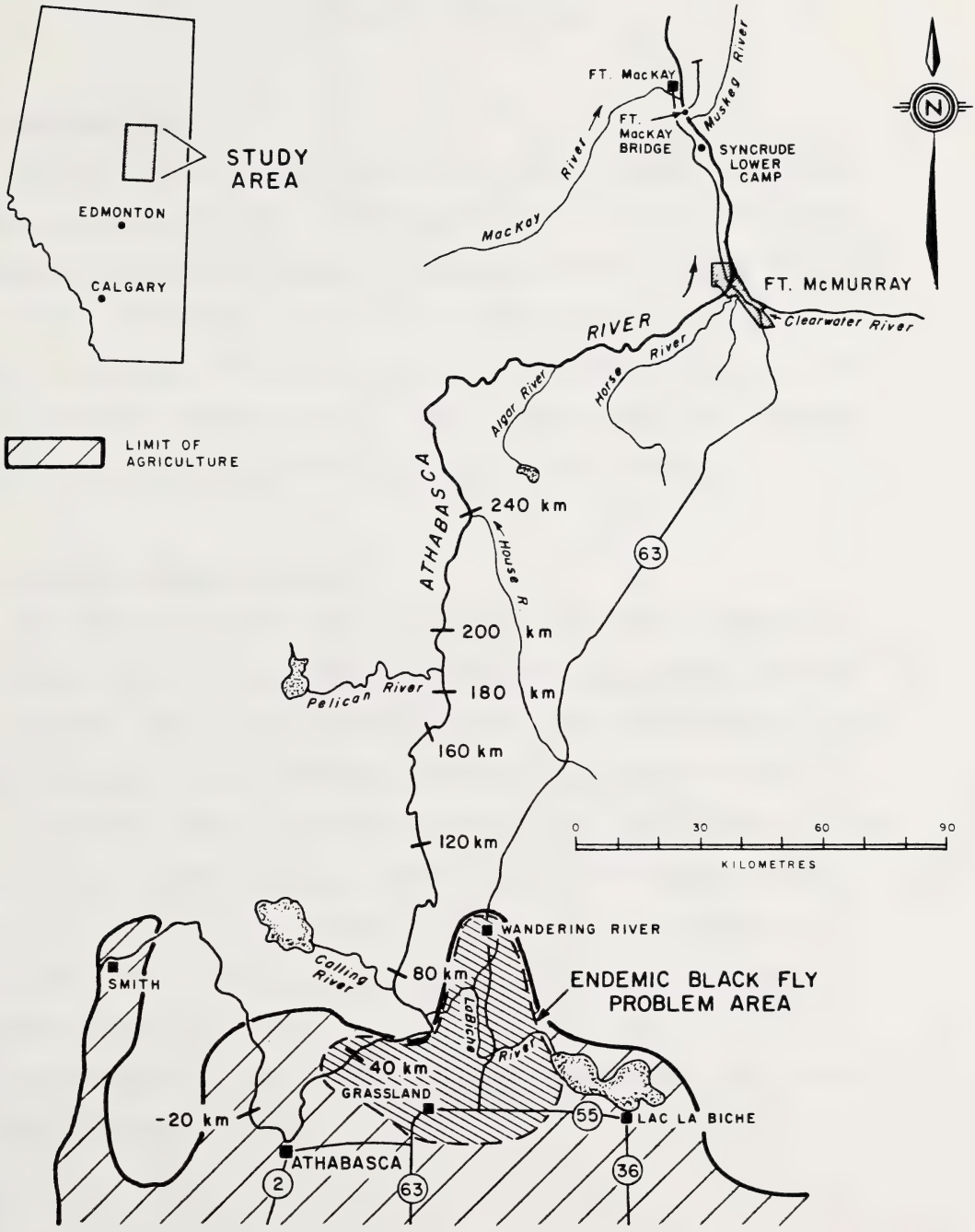

FIGURE 1 - STUDY AREA AND SAMPLING SITES

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2.0 Materials and Methods

2.1 Sampling Sites

Sampling site designation followed the format used in a 1982 study (Byrtus and Jackson, 1984). Eight sampling sites were located on the Athabasca River from 20 kilometres upstream (-20 km) to 240 km downstream of the Town of Athabasca (Figure 1). An additional site at 160 km was added to correspond with a site used by the consultant in charge of the black fly control program (Murray, 1984). Habitat data were collected from all sites during September and are presented in Table 1.

2.2 Discharge and Water Quality

Discharge levels of the Athabasca River at the Town of Athabasca (hereafter referred to as Athabasca) during 1983 are plotted in Figure 2. Turbidity levels using a Horiba Model U-7 Water Quality Checker were taken during the summer at Athabasca and are also plotted in Figure 2.

In addition, temperature, pH, dissolved oxygen, and conductivity were measured with the Water Quality Checker. Data were reduced by taking mean values over five day periods. A simple correlation coefficient matrix was used to measure the relationship between pairs of water quality variables (Table 2).

A coefficient of 1.00 indicates complete agreement for each pair of variables (Bortleson, 1978).

Table 1. Habitat descriptions of eight non-target organism sampling sites Athabasca River, September 1983. (Range of values from three sampling trips).

Distance downstream of Town of Athabasca (km)	-20*	40	80	120	160	180	200	240
Distance from shore (m)	2.0 - 2.5	2.0 - 3.0	3.0 - 3.5	1.5 - 3.0	2.0 - 5.0	2.0 - 3.5	1.5 - 2.0	1.0 - 2.0
Water depth (m)	0.5 - 0.6	0.5 - 0.55	0.45 - 0.5	0.35 - 0.6	0.2 - 0.45	0.45 - 0.55	0.4 - 0.7	0.5 - 0.6
Mean velocity (cm/sec)	37.3 - 73.3	17.3 - 29.3	28.7 - 41.7	44.0 - 55.7	22.7 - 34.3	27.3 - 30.3	28.0 - 35.3	51.0 - 66.7
Substrate composition:								
% > 25 cm	0	5	0	50	10	10	10	0
% > 6 cm	30	40	40	30	40	70	20	40
% > 2 cm	40	45	30	10	40	10	60	40
% > 0.5 cm	30	10	30	10	10	10	10	20
Base composition:	sand/rock	mud/sand	mud/rock	mud/rock	mud/rock	rock	sand/rock	sand/rock

* Site located 20 km upstream of Town of Athabasca

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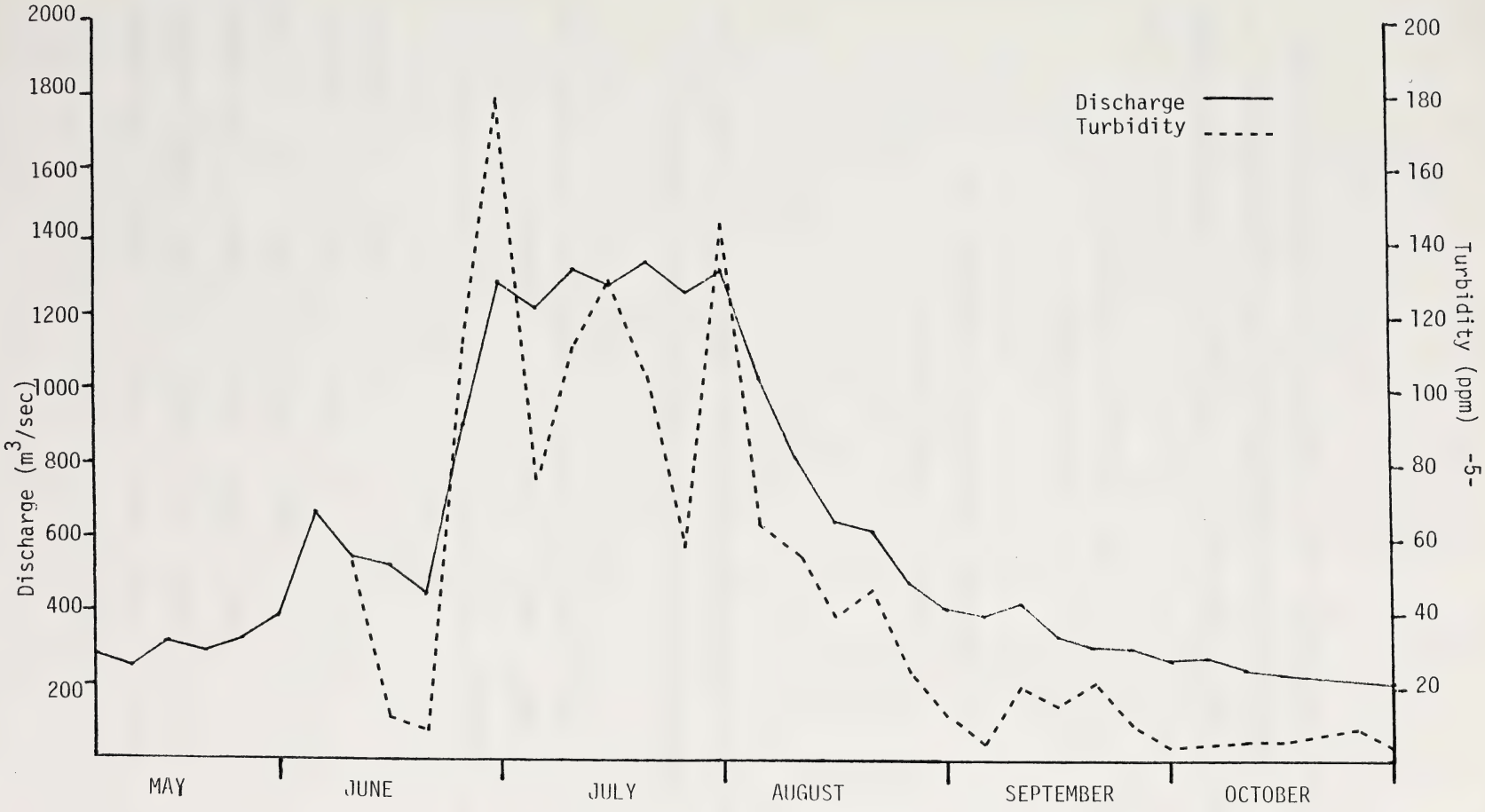

Figure 2 - Discharge and turbidity levels of Athabasca River at Athabasca, 1983
(Discharge data - Water Survey of Canada Station No. 07BE001)

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The paired variables with correlation coefficents greater than 0.75 were discharge/turbidity and also temperature/dissolved oxygen. Regression equations and coefficients of determination (r^2) for these are:

1) discharge (x)/turbidity (y)

$y = 0.107x - 23.75$, $r^2 = 0.81$

2) temperature (x)/dissolved oxygen (y)

$y = 14.102 - 0.292x$, $r^2 = 0.83$.

Table 2. Matrix of correlation coefficients for discharge and five water quality variables from the Athabasca River at Athabasca, 1983.

	Disch.	Turb.	pH	Temp.	Diss. Oxygen	Cond.
Discharge	1.00					
Turbidity	0.90	1.00				
pH	0.09	0.04	1.00			
Temperature	0.68	0.45	0.19	1.00		
Dissolved Oxygen	-0.67	-0.49	-0.15	-0.91	1.00	
Conductivity	-0.20	-0.22	0.00	0.11	0.14	1.00

2.3 Treatment

Monitoring of black fly larval numbers and development by the consultant (Murray, 1984) in May indicated that a treatment utilizing two injection points were required. The first chemical injection was carried out on May 30 at 1745 hours, just downstream of the 80 km sampling site. Here, 240 litres of Sanex Methoxychlor 25E (25% active ingredient, PCP #15092) were injected into a flow of 484 cubic metres per second (m^3/sec) over 7.5 minutes to give an effective dosage of 280 parts per billion (ppb). The second chemical injection (1b) was conducted on May 31 at 1400 hours just downstream of the 160 km sampling site. Exactly 249.48 litres of Sanex Methoxychlor 25E were injected into a flow of 426 m^3/sec over 7.5 minutes to give a calculated dosage of 299 ppb. The river was less turbid than normal because of a lack of rainfall during the month of May

Larval monitoring following these injections indicated that a second treatment would be required. On July 5, at 1700 hours at the 80 km treatment site, 514 litres of Sanex Methoxychlor 25E were injected over 7.5 minutes into a river flow of 1430 m^3/sec to give a calculated dosage of 199 ppb. The river was very turbid at this time because of high discharge levels.

The injection procedure and materials used are described by Depner et al. (1980a). Discharge levels for all three injections were calculated by staff from Survey Branch, Alberta Environment.

2.4 Non-target Organism Sampling

2.4.1 Bottom samples (Rock Tumble)

Non-target invertebrate organisms (NTO's) were collected during the summer at each of the eight sampling sites using the rock tumble method described by Depner et al. (1980b) and Murray (1984). An area of river substrate (0.5 m^2) was disturbed by kicking and dislodging rocks with a garden rake for a one minute period, and the freed organisms and organic debris were collected with a net (mesh size: 405 microns). Three replicate samples were collected at each site for each sampling period. Non-target organism sampling sites were located in riffle areas near the shore and adjacent to the black fly larval sampling sites. The substrate at the sampling sites consisted of large gravel and small rocks, ranging in size from 2 cm to 15 cm. The samples were preserved in 95% denatured ethanol and taken to the laboratory for sorting and identification. Specimens were identified to species where possible, using available identification keys (Allen and Edmunds, 1976; Baumann et al., 1977; Bednarik and Edmunds, 1980; Bednarik and McCafferty, 1979; Berner, 1978; Dosdall and Lehmkuhl, 1979; Edmunds et al., 1976; Flowers, 1980; Flowers and Hilsenoff, 1975; Johnson, 1978; Lehmkuhl, 1984; MacKay, 1978; Morihara and McCafferty, 1979; Ross, 1944; Stark and Gaufin, 1976; Whiting, 1984; and Wiggins, 1977). Nymphs or larvae from many of the genera collected could not be determined to species because of the lack of available references for Western Canada.

Sampling of non-target organisms was conducted jointly by the consultant and the Pesticide Chemicals Branch from ice break-up to September 21. In compliance with the pesticide application permit issued to the County of Athabasca by Alberta Environment, the consultant (Murray, 1984) sampled at sites 40, 80, 120, 160, 200 and 240 km to August 31. The data collected by the consultant are included in the analyses here.

As high river levels in early July precluded sampling, there are gaps in the non-target organism monitoring data.

2.4.2 Drift Sampling

The method of monitoring the immediate impact of the methoxychlor treatment was to observe changes in the downstream drift of the aquatic invertebrates. Drift sampling indicated changes in density and diversity of the invertebrate drift that were not attributed to diel fluctuations.

Density of the drifting benthic invertebrate organisms was monitored by retrieving samplers every 4 hours over a two day period that bracketed the expected time of arrival of the methoxychlor pulse from the upstream treatment site. Sampling of the first treatment began at 0800 hours on May 31 and continued until 0800 hours on June 2. Drift sampling for the second treatment began at 2400 hours on July 5 and continued until 2400 hours on July 6.

The sampling site was 178 km downstream of Athabasca: 98 km downstream of the first injection location (1a - May 30) and 18 km from the second injection location (1b - May 31). The same sampling site was used to monitor the second treatment (July 5). A description and diagram of the sampling site is provided in Haufe et al. (1980a), p.160.

Two types of samplers were used in the drift monitoring program:

i) Three conical drift nets, constructed of 250 micron nitex, were anchored in the river approximately 2 metres from the west shore. The net was 75 cm in length with a 15 cm diameter entrance and a removable screen on the 5 cm diameter end.

The drift nets were changed every 4 hours. Samples were flushed from the net with river water into a plastic tray then filtered through a dip (plankton) net, and transferred to a pint (455 ml) mason jar containing 95% denatured ethanol.

River velocity adjacent to the samplers was measured with a Marsh-McBirney Model 201 portable water current meter. Velocity during the first treatment sampling varied between 25 and 40 cm/sec, and during the second treatment monitoring it was 55 cm/sec.

ii) The other sampler was the modified 'bomb' drift sampler described by Haufe et al. (1980b). Three lines were anchored in the thalweg of the current and held afloat with a large 30 cm diameter styrofoam buoy and a trailing plastic float. From each line a 'bomb' sampler was set at approximately 50 cm below the water surface. These samplers were changed every 4 hours by approaching the set by boat from the downstream end, lifting the line out of the river and removing the drift sampler, processing the sample, replacing the sampler and releasing the line set. River velocity adjacent to the samplers was 145 cm/sec for the first treatment and 180 cm/sec for the second treatment.

The contents of each sampler were flushed into a large plastic tray, strained through the dip net and transferred to mason jars containing 95% denatured ethanol.

The samples from the small drift nets and the 'bomb' samplers were taken to the lab for identification and enumeration.

2.4.3 Statistical Methods

Diversity and dominance indices are two useful measures in monitoring the species structure of a community based on the total numbers of organisms and total number of taxa present. The Shannon - Weaver Diversity Index reflects a possible unstable community structure when the index is of a low numerical value. Because natural situations, such as a large hatch of one taxon, may result in a sample having a low value diversity index, a critical analysis of the data must be made to

determine whether any changes of magnitude between two sampling periods are natural or induced by an environmental disturbance.

The diversity index of pre and post-treatment samples was calculated using the Shannon - Weaver function as expressed by Smith (1974):

$$d = c\ (\log_{10} N - (1/N \Sigma\ Ni\ \log_{10}\ Ni)$$ where:

c = 3.32198

N = total number of organisms in the sample

Ni = total number of organisms in each taxa

The dominance index is useful in showing whether a community is dominated by a few taxa or by a variety of taxa. The closer the index is to 1.00, the more the dominance is concentrated to one species. Dominance indices for pre and post-treatment samples were calculated using the Odum (1971) formula:

$$c = \Sigma\ (ni/N)^2$$, where:

ni = number of organisms in each taxa

N = total number of organisms in the sample.

After preliminary statistical analysis of diversity, dominance and population fluctuations had been completed, data from Appendices 1-19, habitat data, water quality data and discharge was entered into the University of Alberta computing system for further analysis. Data were converted to z-scores for the majority of analyses (the z-score transformation standardizes variables with different observed scales to the same scale).

The size of the data base was reduced by grouping the sampling periods (weeks) as outlined below:

Label	Sampling Period (Appendix No.)
deleted	1,2
pre 1st	3,4
post 1st	5,6
pre 2nd	7,8,9
post 2nd	10,11,12,13
post	14,15
final	16,17,18,19

This grouping resulted in 6 sampling periods instead of the original 19.

Taxa were analyzed individually or grouped into genera or family, depending on the number of organisms and the detail of analysis required.

Sites 40 km and 160 km were deleted from certain calculations when preliminary analysis indicated lower mean frequencies than adjacent sites:

Site	Frequency*	
- 20	14.419	
40	9.122	control sites
80	10.091	
120	11.527	
160	5.082	
180	12.634	treated sites
200	7.047	
240	9.601	

*Frq = $\frac{N}{t(sp)}$ where N = total number of organisms/site
t = number of taxa (50)
and sp = number of sampling periods where samples were collected at that site.

This deletion served to further reduce the amount of data for plotting purposes, and reflected observations made over the years regarding the difficulty of consistently sampling these two sites.

Cluster analysis using SPSS-x (SPSS Inc.,1983) was initially conducted on raw data variables, z-score transformed data variables, and the accumulation of both raw and transformed data. Variables included week, site, frequency (mean number of organisms/site/week), discharge, temperature, dissolved oxygen, pH, conductivity, turbidity, and site habitat characteristics. The SPSS-x cluster analysis procedure used squared Euclidean distance to measure qualitative and quantitative similarities among the benthic data.

The initial cluster analysis was largely unsuccessful because of the large number of samples (129) and because some of the variables for particular weeks were missing, subsequently, after deleting variables with excessive missing values (e.g. habitat characteristics), cluster analysis using the Clustan C-1 programme (Wishart, 1978) was conducted. Benthic data from Appendices 1 - 19 were analyzed: 1) to assess phenological characteristics or to determine if pre and post-treatment invertebrate populations clustered together; 2) to compare sites by grouping the ones with similar zoobenthic composition; and 3) to assess comparisons between the 19 sampling periods (weeks) involved in the 1983 program.

2.5 Methoxychlor Residues - Water

One litre water samples were collected one day after treatment at several locations approximately 150 to 200 km upstream of Fort McMurray to determine methoxychlor residue levels. Samples were flown to the Alberta Environmental Centre in Vegreville for analysis and the results were telephoned to the the City of Fort McMurray's water treatment plant operator. This procedure, which was completed in one day, was conducted for both treatments.

In conjunction with NTO drift sampling at 178 km, water samples were collected during the passage of the chemical pulse. A series of three samples were collected every four hours: from the east bank, west bank and from the centre of the river.

Additional water samples were collected from five areas in the vicinity of Fort McMurray during the passage of the methoxychlor contaminated water: 1) the raw water reservoir and the water treatment plant at Fort McMurray; 2) the river at the Highway 63 bridge at Fort McMurray (396 km downstream of Athabasca); 3) the river at the Syncrude water intake (433 km downstream) and from the reservoir used for their lower camp water supply; 4) the river at the Highway 63 bridge near Fort Mackay (446 km downstream); and 5) the river at the hamlet of Fort Mackay (452 km downstream). These samples were collected near the shoreline.

Analyses were carried out by the Chemistry Wing, Alberta Environmental Centre, Vegreville.

2.6 Methoxychlor Residues - Sediment

Sediment samples were collected with a core sampler from the Athabasca Delta area near Lake Athabasca in late September, 1983. Samples were collected in shallow water in areas of high sedimentation (shoreline, sandbars) in the channels leading into and out of the Lake (Figure 3). Samples were not collected from depositional areas in the Lake itself because of very rough water conditions during the sampling trip.

Samples were analyzed for methoxychlor, chlorinated herbicide acids, and organochlorine pesticide residues by the Chemistry Wing, Alberta Environmental Centre, Vegreville.

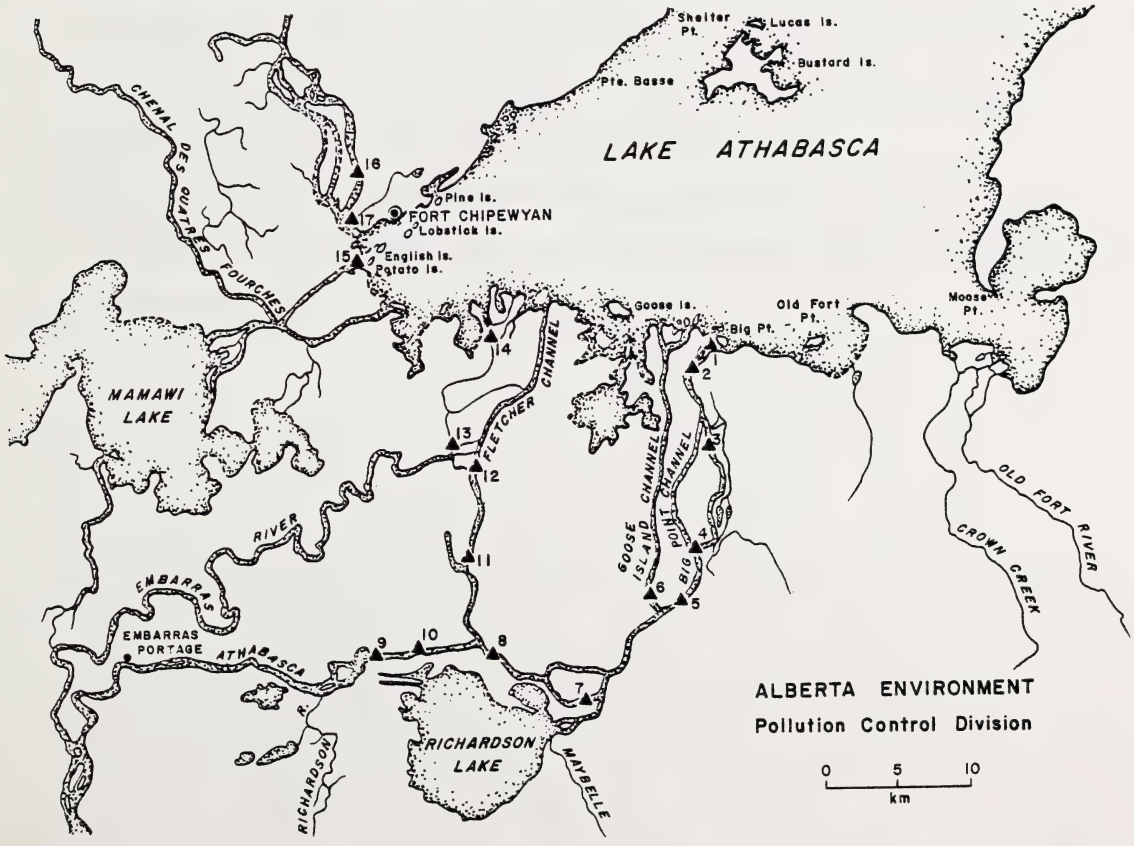

Figure 3. Location of sample sites in the delta of the Athabasca River in northern Alberta .

2.7 Adult Black Fly Sampling

Three methods of sampling for adult black flies were used in this study. 1) Barrel traps (Byrtus, 1981), in use since 1979, were placed in two locations in the farming area affected by black flies. Four traps were set up in each of the pastures of G. Lantz near Grassland (SE 1/4, Sec. 20, Twp. 68, R. 19, W 4th), and A. Mitchell near Wandering River (SE 1/4, Sec. 20, Twp. 72, R. 17, W 4th). The Tanglefoot® covered plastic liner on these traps was changed weekly and taken to the laboratory to count the black flies trapped on the plastic.

2) Three silhouette traps (Fredeen, 1961 and Shipp, personal communication, 1982) were also used on both the Lantz and Mitchell farms. The design of the trap was described by Byrtus and Jackson (1984). Collecting jars were changed weekly.

3) Three samples of 20 sweeps each with a standard 0.3 m diameter insect net were collected weekly from the vicinity of the cattle present at each farm.

3.0 RESULTS

3.1 Treatment

The treatments in 1983 were effective in reducing larval black fly numbers. Data presented by Murray (1984 - Table 3) showed reductions in larval black fly sample numbers ranging from 95.9 to 99.2% following the first treatment. Following the second treatment, reductions in larval sample numbers ranged from 98.3 to 100%.

A graphical representation of black fly larval numbers at treated and untreated sites is given in Figure 4. The figure indicates that the methoxychlor had a significant impact on larval sample numbers following each treatment. Increases in sample numbers in the week following post-treatment samples were caused by hatching of black fly eggs and the appearance of early instar larvae (Murray, 1984).

3.2 Non-Target Organism Sampling

3.2.1 Bottom Samples (Rock Tumble)

Population trends of non-target organisms were monitored in order to determine whether population changes were natural or related to the methoxychlor treatment program. Collections were made upstream and downstream of Athabasca at eight sites, from early May to late September. The results of these collections are presented in Appendices 1- 19.

As described by Wilhm (1972), a clean water benthic community has a dominance index of around 0.10, and an enriched (possibly polluted) community has a dominance index as high as 0.90. Table 3 indicates that on only a few sampling periods did the dominance index of a sample approach the 0.70 -0.80 range.

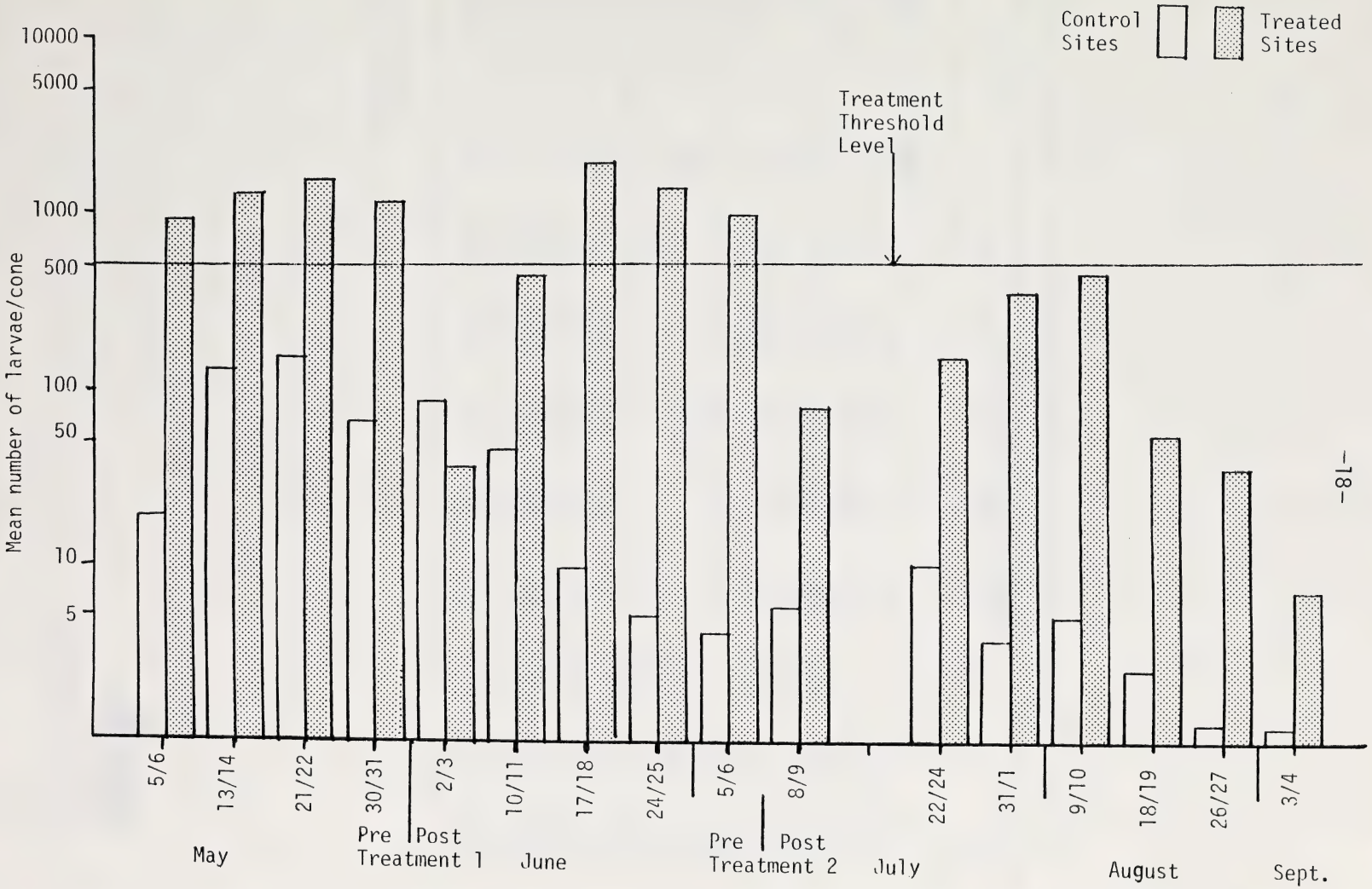

Figure 4 - Mean black fly larval numbers at control (40 and 80 km) and treated (120, 160, 200 and 240 km) sites during 1983 (Data from Murray, 1984)

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Table 3. Dominance indices of non-target organism samples from eight sites during 1983.

		Distance downstream of Athabasca							
		-20	40	80	120	160	180	200	240
Week	Number								
May 3 - 6	1	0.31	0.18	0.15	0.21	0.15		0.31	0.19
May 11 - 13	2	0.33	0.38	0.28	0.19	0.38		0.26	0.31
May 18 - 20	3	0.27	0.67	0.58	0.28	0.58		0.21	0.17
May 24 - 31	4*	0.56	0.49	0.18	0.57	0.610	0.25	0.30	0.22
June 1 - 3	5**		0.75	0.39	0.23	0.32	0.53	0.24	0.59
June 6 - 11	6	0.35	0.50	0.18	0.14	0.33	0.50	0.22	0.22
June 14 - 20	7	0.22	0.36	0.13	0.33	0.58	0.41	0.15	0.34
June 24 - 26	8		0.17	0.18	0.22	0.24		0.16	0.23
July 5 - 6	9*			0.19				0.25	0.29
July 8 - 13	10**			0.16			0.21	0.45	0.12
July 14 - 22	11	0.21					0.18	0.48	0.17
July 31 - Aug 3	12	0.53					0.15	0.27	0.21
Aug. 8 - 10	13	0.33	0.25	0.31	0.25	0.16	0.17	0.25	0.25
Aug. 17 - 19	14	0.22	0.26	0.30	0.21	0.22	0.24	0.23	0.22
Aug. 24 - 26	15	0.39	0.21	0.27	0.39	0.12	0.28	0.23	0.28
Aug. 30 - 31	16	0.43	0.54	0.41	0.30	0.18	0.20	0.20	0.21
Sept. 7 - 8	17	0.19	0.24	0.26	0.16	0.21	0.18	0.12	0.16
Sept. 14 - 15	18	0.44	0.38	0.45	0.58	0.32	0.40	0.32	0.23
Sept. 21	19	0.31	0.25	0.26	0.16	0.22	0.23	0.13	0.19

* Pre treatment
** Post treatment

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During the May 18-20 sampling period, the 40 km sampling site had a 0.67 dominance index, caused by the large number of Chironomidae in the sample. During this same period the abundance of Chironomidae increased the dominance index at the 80 km and 160 km sites as well.

The 40 km site showed the highest dominance index (0.75) during the post treatment sampling period June 1-3, caused by a new hatch of Metretopus borealis.

During the post treatment sampling periods, several sites had a predominance of Chironomidae larvae, which caused a higher than average dominance index (i.e., sites 40 km and 180 km on June 6 - 11). These sites appeared to be anomalous compared to the rest of the sites during the same sampling period.

By early August the dominance index at all sites was at a low level, and remained so until the end of the sampling program.

The diversity index reflects a possible unstable community structure when the index is of a low numerical value. Data from Table 4 indicate low diversity index values corresponding with the high dominance indices already discussed. A closer examination of a select number of dominant genera is necessary to determine why the dominance indices are high, and/or the diversity indices are low.

Of the 50 taxa found in the non-target samples, there are relatively few occurring throughout the summer that were abundant enough to make any reliable observations concerning dramatic population changes. Figures 5-13 present the population fluctuations of a select number of species from the major taxonomic orders.

Ephemeroptera are an important component in the Athabasca River benthic community, in both numbers of taxa and number of organisms.

Table 4. Diversity indices of non-target organism samples from eight sites during 1983.

		Distance downstream of Athabasca							
		-20	40	80	120	160	180	200	240
Week	Number								
May 3-6	1	2.17	2.92	3.16	2.92	3.09		2.29	2.48
May 11 - 13	2	2.14	2.02	2.50	2.78	2.14		2.19	2.17
May 18 - 21	3	2.43	1.26	1.59	3.05	1.48		2.74	3.07
May 24 - 31	4*	1.53	1.63	2.96	1.51	1.27	2.42	2.03	2.66
June 1 - 3	5**		0.94	1.59	2.46	2.19	1.55	2.50	1.49
June 6 - 11	6	2.34	1.53	3.00	3.15	2.10	1.76	2.69	2.51
June 14 - 20	7	2.83	2.33	3.23	2.33	1.49	2.30	3.10	1.92
June 24 - 26	8		2.89	2.86	2.75	2.47		3.09	2.70
July 5 - 6	9*			2.88				2 11	2.47
July 8 - 13	10**			3.06			2.76	1.92	3.56
July 14 - 22	11	2.68					2.90	1.97	3.00
July 31 - Aug 3	12	1.58					3.15	2.37	2.57
Aug. 8 - 10	13	2.15	2.58	2.14	2.51	2.97	2.92	2.57	2.74
Aug. 17 - 19	14	2.68	2.36	2.30	2.71	2.73	2.58	2.76	2.81
Aug. 24 - 26	15	1.80	2.61	2.38	1.93	3.32	2.50	2.67	2.45
Aug. 30 - 31	16	1.85	1.64	2.07	2.44	2.80	2.92	2.28	2.80
Sept. 7 - 8	17	2.82	2.70	2.53	2.98	2.72	3.04	3.34	2.99
Sept. 14 - 15	18	1.79	2.40	1.95	1.51	2.27	2.15	2.43	2.55
Sept. 21	19	2.37	2.52	2.38	3.04	2.74	2.58	3.30	2.93

* Pre treatment
** Post treatment

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The species that were frequently collected in large numbers include; Baetis tricaudatus, Ephemerella inermis, Rhithrogena undulata, Heptagenia pulla and Heptagenia adequata.

Baetis tricaudatus populations (Figure 5) peaked at most sites around the May 24-31 sampling period, and subsequently declined in numbers, indicating a probable emergence. The population peaked again on June 25 at all sites except -20 km, where the peak had occured two weeks earlier. This second peak was followed by another emergence at about the same time as the second treatment. By the middle of August Baetis populations returned to fairly high levels. Edmunds et al. (1976) reports B. tricaudatus may have more than two generations per year, and Ciborowski and Clifford (1983) reported that B. tricaudatus produce three cohorts per year, in line with the population trends indicated in Figure 5.

Ephemerella inermis (Figure 6) were present in high numbers at all sites during the first sampling period in early May. An emergence occured at sites -20 km to 180 km in the following week, and at sites 200 km and 240 km a week later. Following the first treatment the population of E. inermis fluctuated throughout the summer. Numbers of E. inermis increased weekly during September until sampling ended.

Rhithrogena undulata populations followed a trend similar to that of Ephemerella inermis. R. undulata had an emergence between the May 18 - 20 sampling period and the May 24 - 31 sampling period (Figure 7). Edmunds et al. (1976) stated that Rhithrogena is univoltine. Rhithrogena eggs probably hatch in late summer, overwinter as nymphs and emerge as adults the following spring. This is comparable with the R. undulata populations observed from the Athabasca River. Following the period of limited sampling in July, the first two sampling periods in August reveal an increase in numbers of Rhithrogena nymphs.

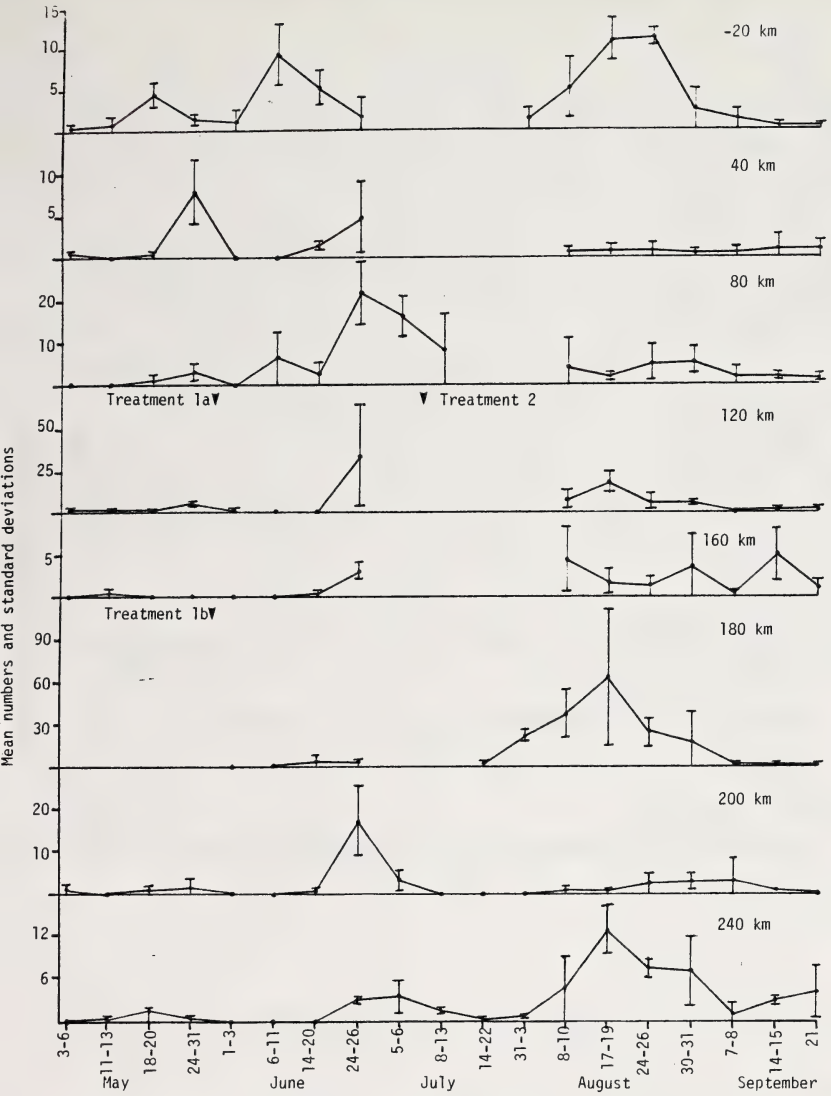

Figure 5 - Population fluctuations of *Baetis tricaudatus* at eight sites on the Athabasca River, 1983

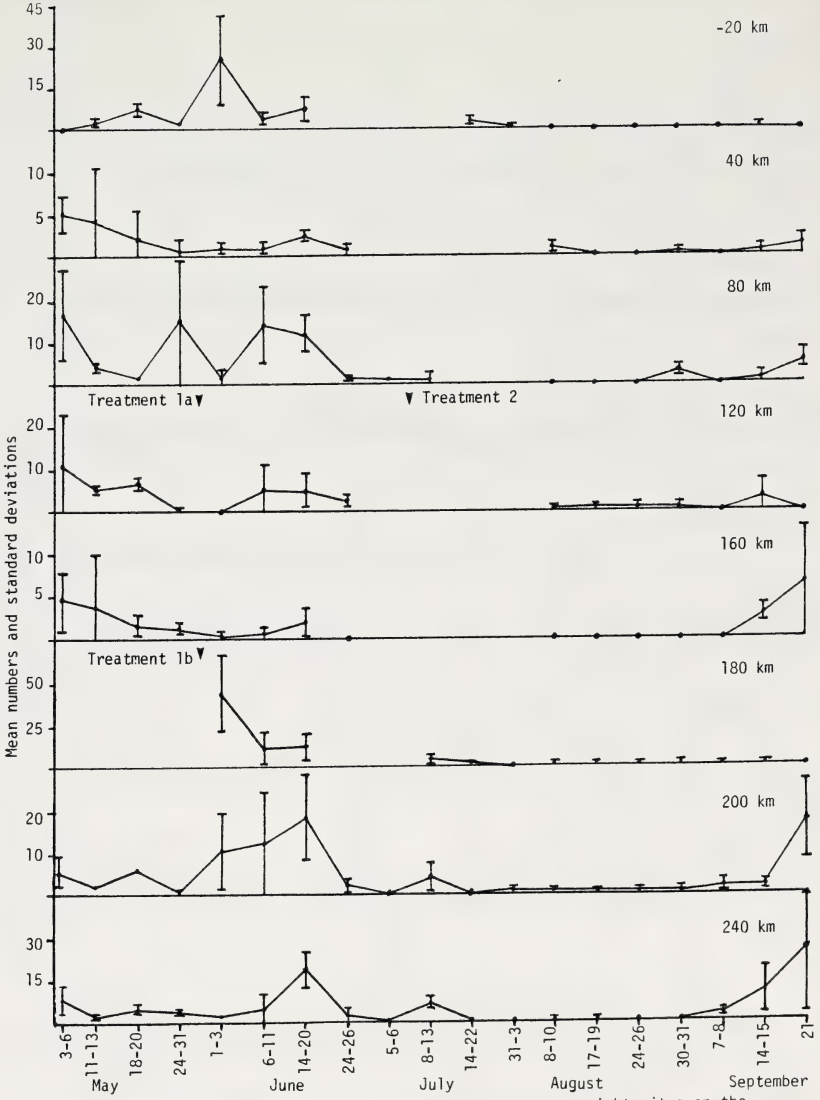

Figure 6 - Population fluctuations of *Ephemerella inermis* at eight sites on the Athabasca River, 1983

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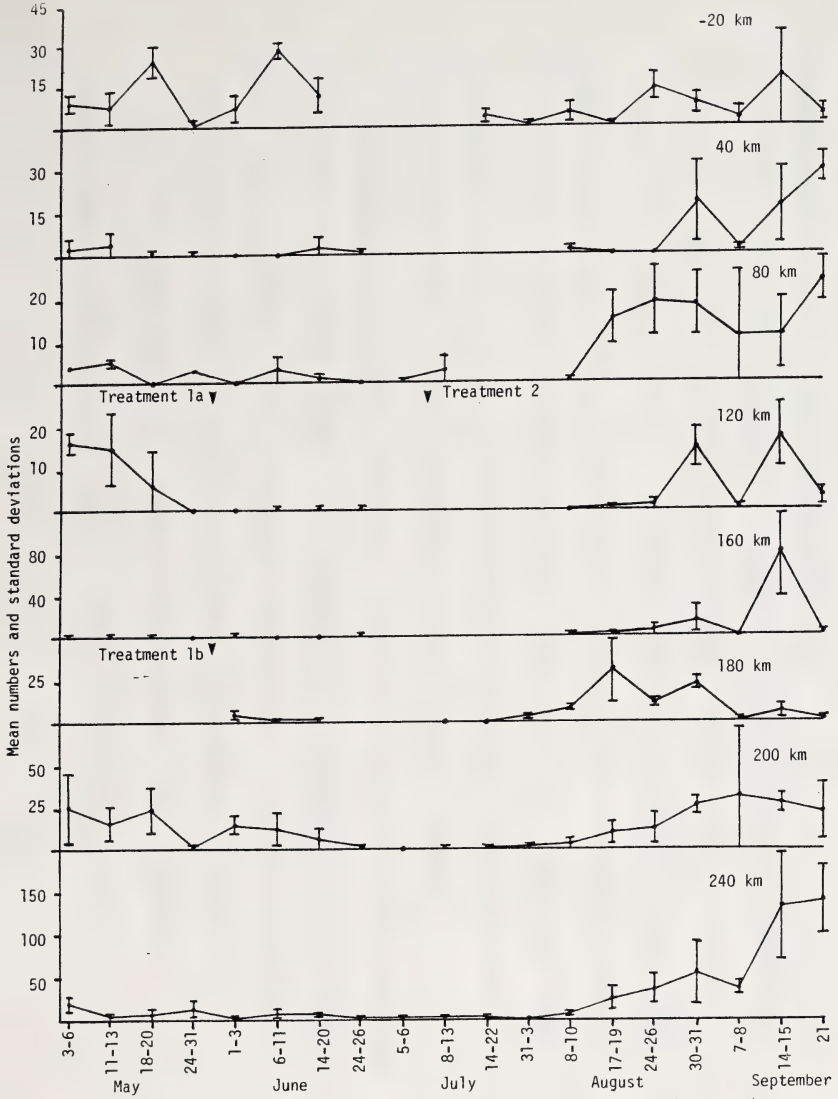

Figure 7 - Population fluctuations of *Rhithrogena undulata* at eight sites on the Athabasca River, 1983

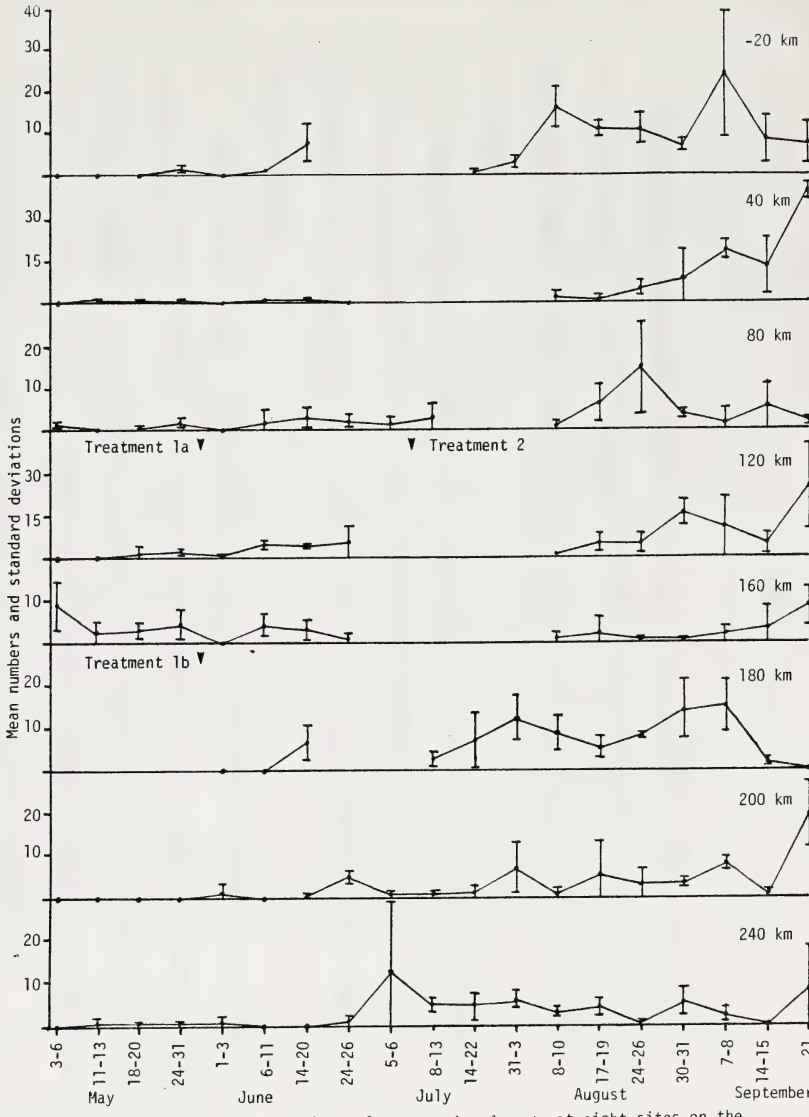

Figure 8 - Population fluctuations of *Heptagenia adequata* at eight sites on the Athabasca River, 1983

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Heptagenia adequata (Figure 8) was not present in large numbers at any sites until July. Following the July 8-13 sampling period H. adequata numbers fluctuated at all sites until the end of the sampling program.

Heptagenia pulla (Figure 9) increased at all sites (except 180 km) from late July to the end of the sampling program. However, at 180 km following the September 7 sampling period, H. pulla dropped in numbers considerably.

Numerous species of Ephemeroptera were found sporadically over the sampling periods but not in sufficient numbers to detect any phenological trends. However, it is vital to maintain complete records from year to year, in order to detect whether any of these species are being displaced from the community. Some of these organisms include Ameletus sp., Ametropus neavei, Isonychia sp., Leptophlebia sp., Metrotopus borealis, Siphoplecton sp., and Tricorythodes minutus.

In the Plecoptera, Isoperla longiseta (Figure 10) has an emergence period beginning in mid June and lasting until about the end of July (Dosdall and Lehmkuhl, 1979). At sites 200 km and 240 km, I. longiseta numbers peaked about May 30 and decreased during the following sampling period by 97%. The peak and subsequent emergence of I. longiseta were apparently delayed by a couple of weeks at the other sites. At the -20 km and 40 km sites a late emergence occured in early August.

Isogenoides sp. appears to have a one year life cycle with emergence in May and early June (Figure 11). Numbers of Isogenoides sp. collected were very low at all sites following the June 14 - 20 sampling period. Post treatment samples, following the July 5 treatment, showed an increase in Isogenoides sp. numbers at all sites. The increase demonstrated the late summer hatch of this univoltine species.

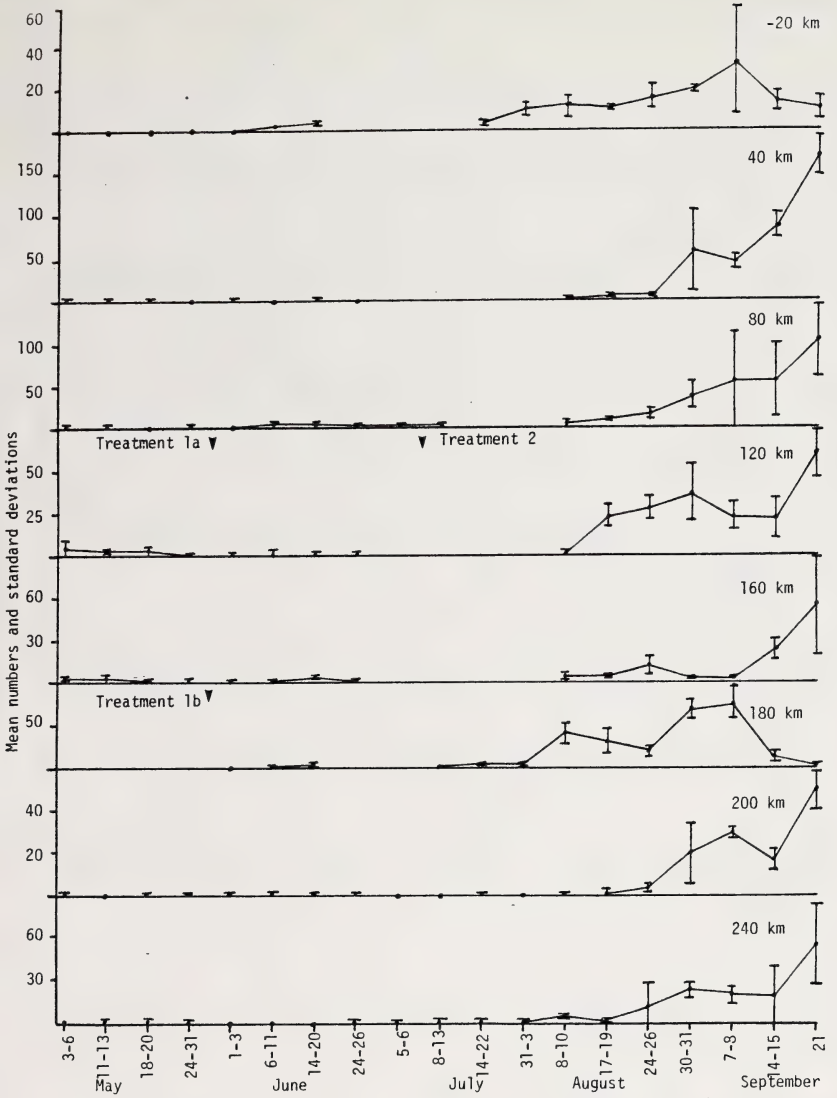

Figure 9 - Population fluctuations of *Heptagenia pulla* at eight sites on the Athabasca River, 1983

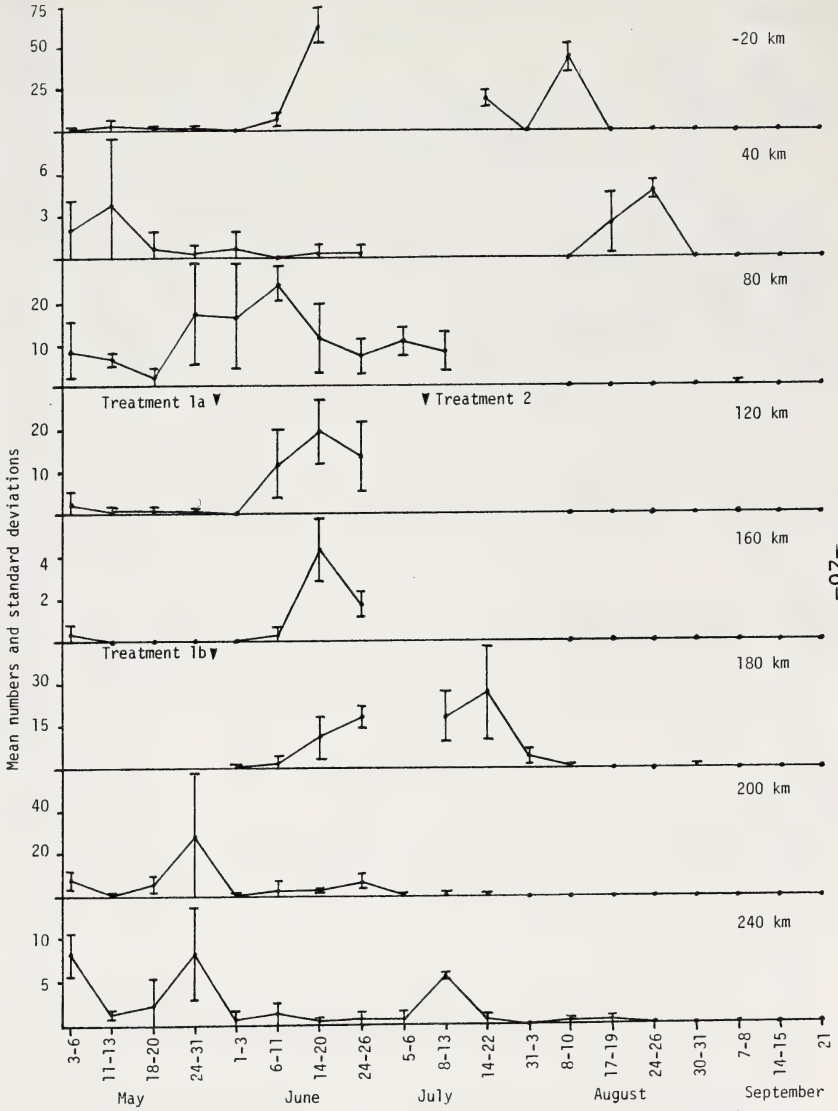

Figure 10 - Population fluctuations of *Isoperla longiseta* at eight sites on the Athabasca River, 1983

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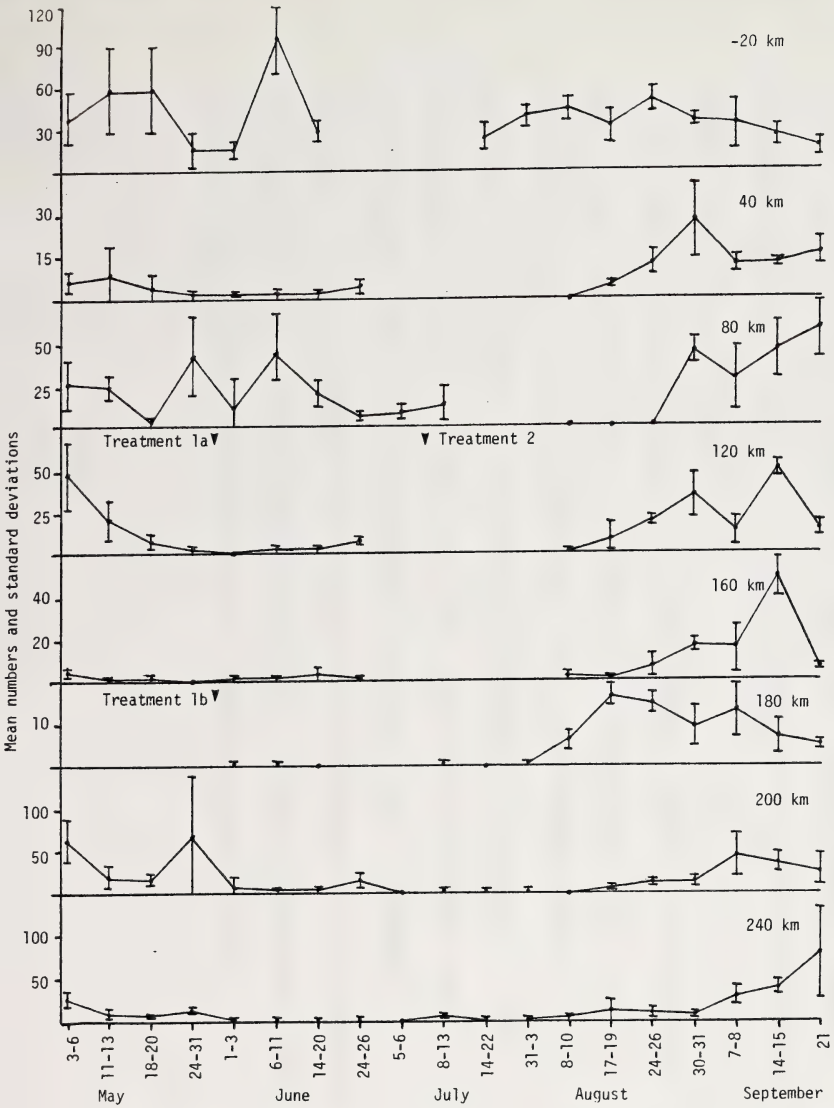

Figure 11 - Population fluctuations of *Isogenoides sp.* at eight sites on the Athabasca River, 1983

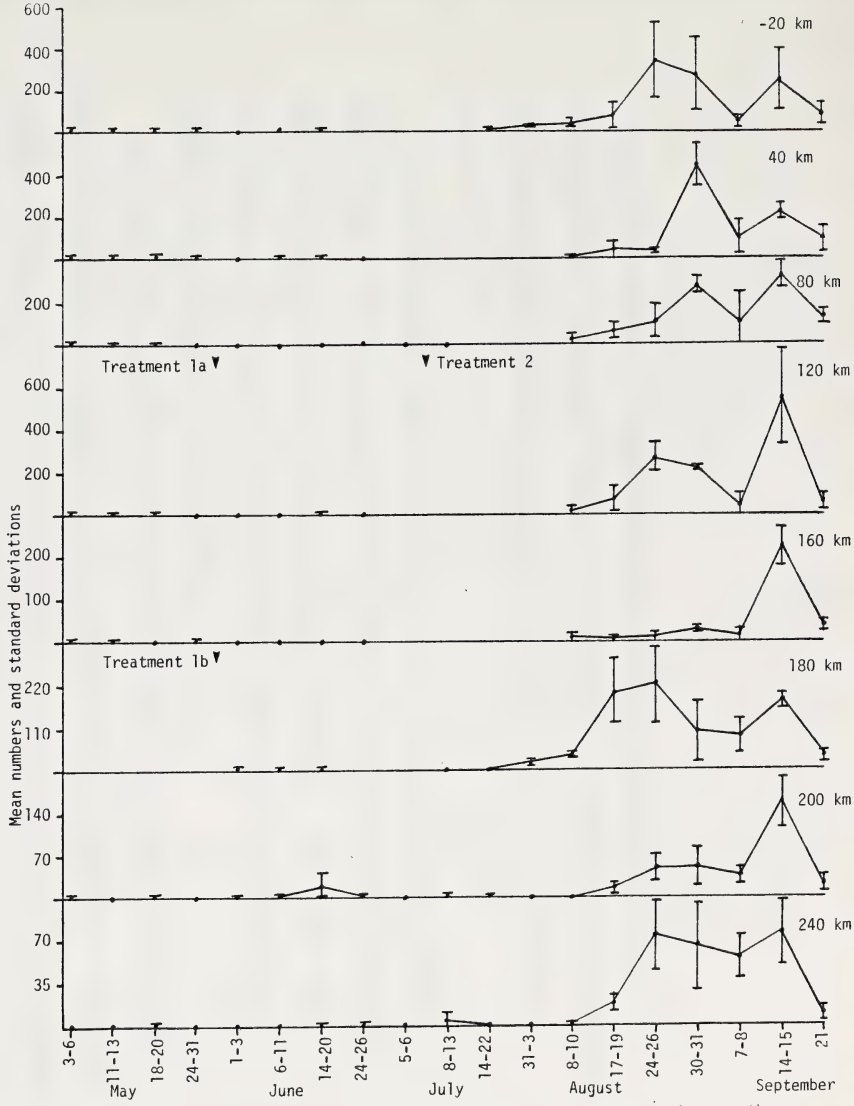

Figure 12 - Population fluctuations of *Chewmatopsyche spp.* at eight sites on the Athabasca River, 1983

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Very low numbers of Cheumatopsyche spp. and Hydropsyche spp. were collected until late July (Figures 12 and 13). Therefore, the effect of each methoxychlor treatment on these organisms cannot be adequately assessed.

Cluster analysis (Section 2.1.3) was also used to assess benthic data. Figure 14 illustrates the hierarchical classification analysis that groups the sites with similar characteristics. The scale on the left refers to the degree of separation: the higher the value, the greater the separation (dissimilarity).

The level of separation between sites was relatively close in this case. An arbitrary selection of the 2.000 level of separation resulted in three clusters. The first cluster was a solitary site (-20 km) which was a productive site throughout the season.

The second cluster included sites 80, 120, 180 and 240 km. These sites were the most consistent in terms of productivity and accessibility during river level fluctuations.

The third cluster included sites 40, 160 and 200 km. The 40 km and 160 km sites occur in areas of the Athabasca River where it is very difficult to find consistent sampling spots, and numerous sample collections were missed during periods of rapidly rising water. The productivity of these two sites was also lower than the other sites. For these reasons, the sites were dropped from some of the following analyses. It was unexpected to find site 200 km included in this cluster as it was a reliable, fairly productive site. Sampling substrate at this site was substantially different than at sites 40 km and 160 km.

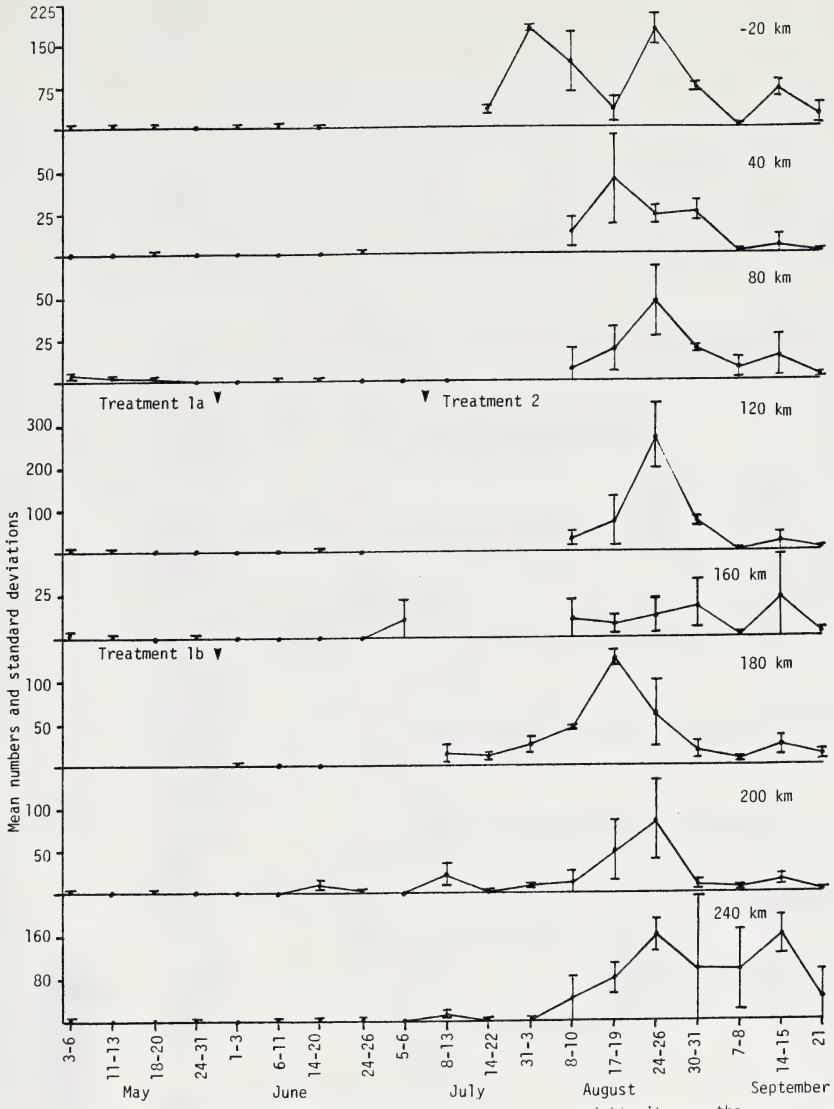

Figure 13 - Population fluctuations of *Hydropsyche spp.* at eight sites on the Athabasca River, 1983

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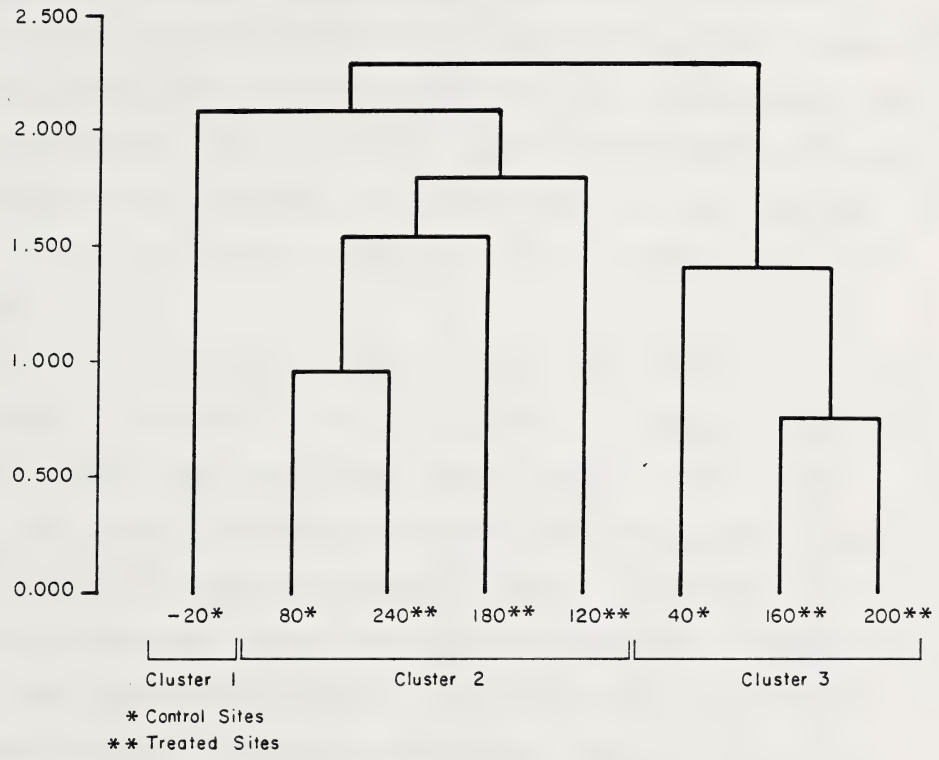

Figure 14 CLUSTER ANALYSIS DENDROGRAM OF EIGHT SAMPLING SITES ON THE ATHABASCA RIVER, 1983.

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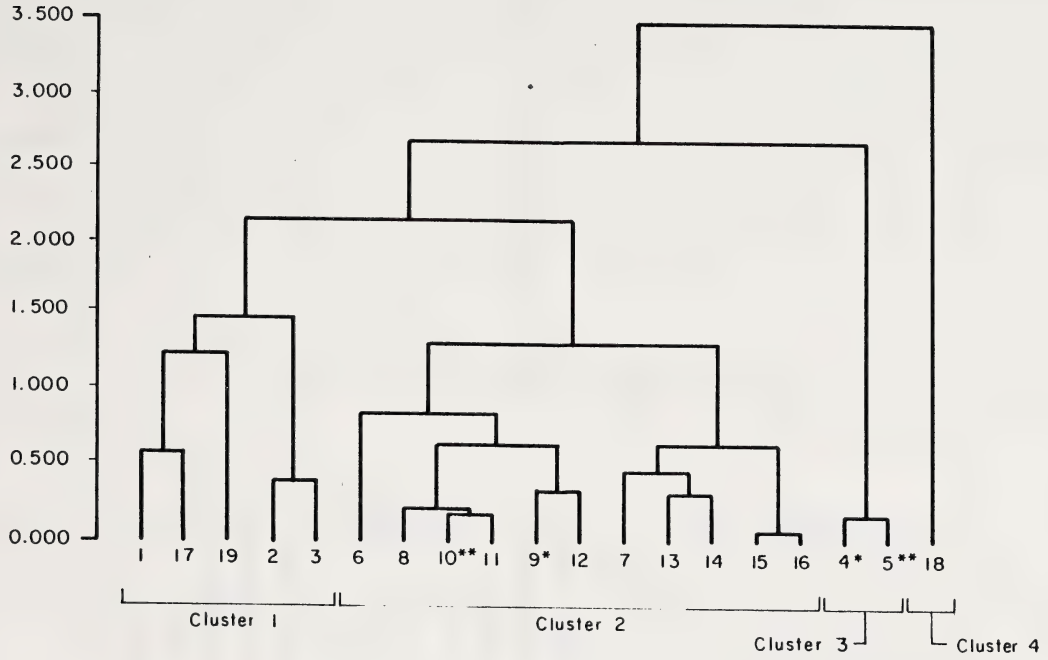
Figure 15 illustrates the dendrogram that clusters the sampling periods (weeks). Sampling periods before and after the first treatment clustered out very early, indicating that the overall composition of the two sampling periods was very similar. Sampling periods before and after the second treatment clustered out somewhat later with other sampling periods in June and July when sample collections were missed because of high water.

The arbitrary selection of 2.000 as a level of separation resulted in four clusters. The first cluster was composed of early May and late September samples (both ends of the sampling season). The second cluster, the largest, included all midsummer samples from June through August (including the high water period of July). The third cluster contained two sampling periods, before and after the first treatment. The fact that these sampling periods clustered together indicates that invertebrate phenology/emergence outweighed the impact of methoxychlor treatment on invertebrate populations. The fourth cluster included only a single sampling period (September 14-15) and the reasons for this are unknown.

Figure 16 is the dendrogram that clustered the reduced data set of sites and sampling periods. Arbitrary selection of 0.500 as a level of separation resulted in four clusters. The first two clusters had a mix of pre and post-treatment sampling periods and encompassed all of the sampling sites. Some of the pre and post-treatment samples clustered very closely (i.e. 240 km Pre 2 and Post 2). The third cluster included control and treated sites from later in the season. The fourth cluster included two sites (-20 and 180 km), both during August.



1 May 3 – 6
2 May 11 – 13
3 May 18 – 20
4* May 24 – 31 (pre-treatment)
5** June 1 – 3 (post-treatment)
6 June 6 – 11
7 June 14 – 20
8 June 24 – 26
9* July 5 – 6 (pre-treatment)
10** July 8 – 13 (post-treatment)
11 July 14 – 22
12 July 31 – Aug. 3
13 Aug. 8 – 10
14 Aug. 17 – 19
15 Aug. 24 – 26
16 Aug. 30 – 31
17 Sept. 7 – 8
18 Sept. 14 – 15
19 Sept. 21

Figure 15 CLUSTER ANALYSIS DENDROGRAM OF NINETEEN SAMPLING PERIODS DURING 1983.

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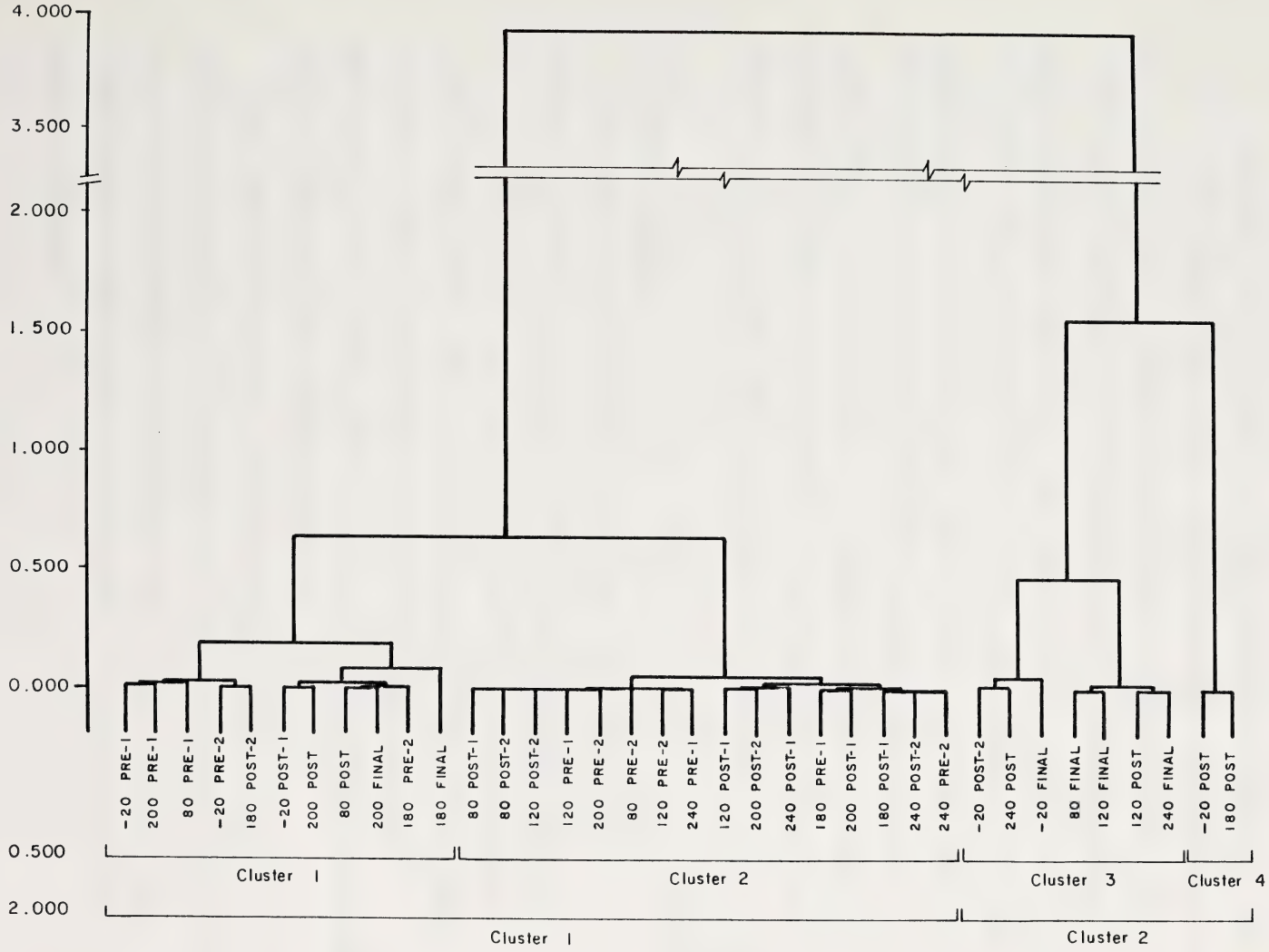

Figure 16 CONDENSED DATA CLUSTER ANALYSIS DENDROGRAM OF SAMPLING SITES AND SAMPLING PERIODS, 1983

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At the 2.000 level of separation, two clusters were observed. The first was the largest with 27 out of 36 site/sampling period combinations and included nearly all sites sampled during May, June and July. The second cluster consisted of sites sampled during the latter sampling periods (August and September). This indicates that a major shift in invertebrate composition occurred late in the sampling season. The two groupings did not cluster out until almost 4.000, a very high level of dissimilarity relative to the clustering of pre and post-treatment samples taken in early mid-summer. It appears that natural changes in invertebrate composition were greater in magnitude than methoxychlor induced changes, as determined by this method of analysis.

3.2.2 Drift Samples

Drift and residue data from 178 km for the May treatment are presented in Figure 17. The mean numbers of the four major orders of invertebrates collected are plotted on a Log (N + 1) scale because of large variances in the means (Appendices 20 and 21) and a large range in numbers of organisms collected during different sampling periods. Methoxychlor residue results (Table 6) are plotted immediately underneath the drift sample data for comparative purposes.

Drift sampler collections peaked at 2400 hours on May 31, the sampling period following the peak passage of the methoxychlor. A slight increase in drift density was observed at 0400 on June 2, either from a slight increase in methoxychlor residue levels or possibly from a diel behavioral response.

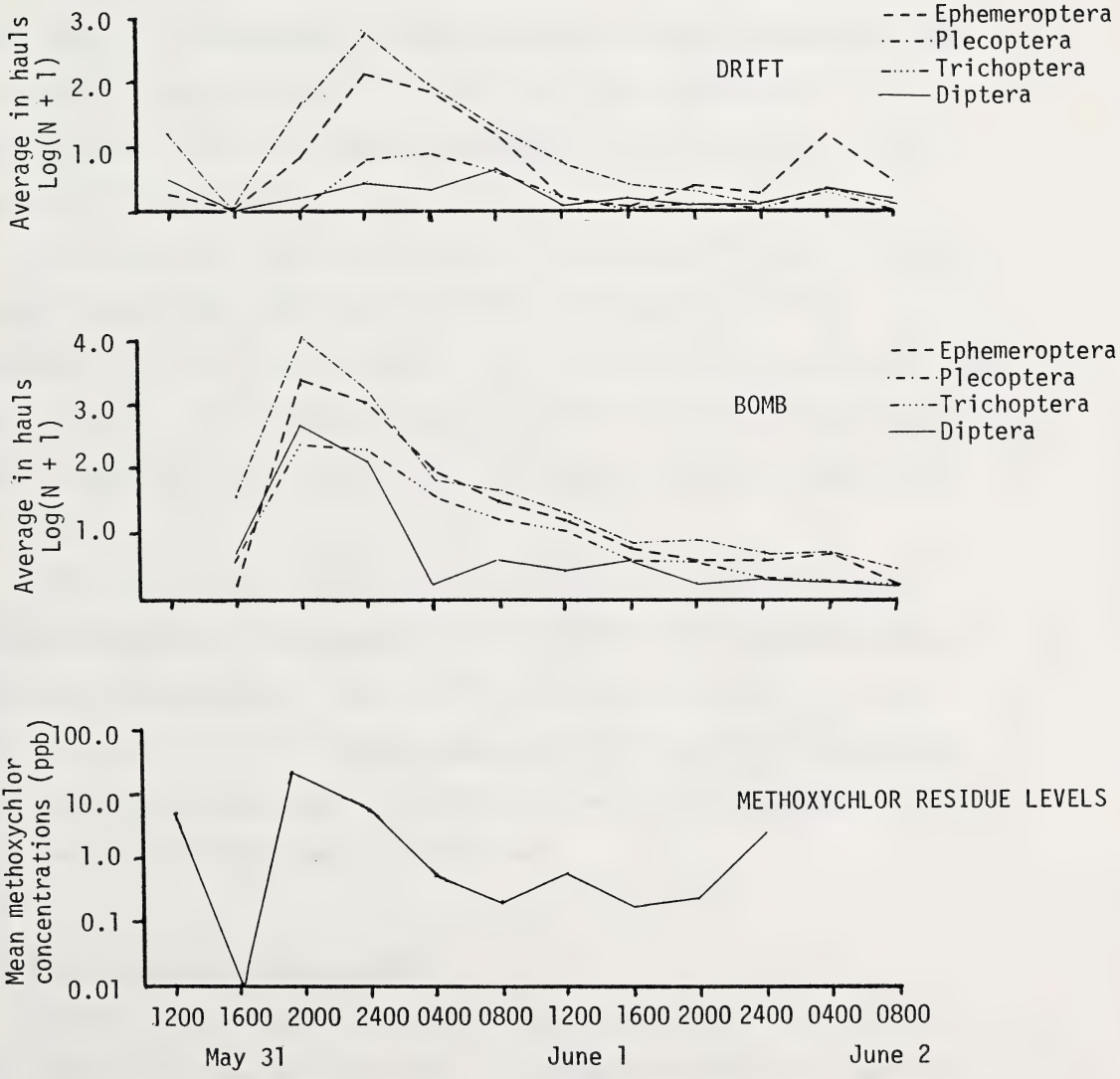

Figure 17 - Mean haul of invertebrates from drift net and bomb samples collected on May 31 - June 2, 1983 at 178 km; with mean methoxychlor residue levels

The bomb sampler collections peaked at 2000 hours on May 31, (the same time as the methoxychlor levels peaked) then tapered off gradually. A slight increase at 0400 on June 2 was also observed.

During the May sampling, the Ephemeroptera and Plecoptera dominated the samples. Rhithrogena undulata, Hastaperla brevis, Isogenoides sp. and Isoperla longiseta were in greatest abundance (Appendices 20 and 21). Diptera (including Simulium arcticum) and Trichoptera were not present in large numbers in the drift.

The July 6 drift and residue data are presented in Figure 18. Bomb sampler collections peaked at 1200 hours, the same time as the methoxychlor residue levels peaked. Drift net collections peaked at 1200 hours as well. The increase observed at 2400 hours did not correspond to the methoxychlor residue levels and is thought to be a diel behavioral response.

Drift net samples (Appendix 22) were dominated by Ephemeroptera (Baetis dardanus, B. tricaudatus) and Plecoptera (mainly Isogenoides sp. and Isoperla longiseta). Bomb sampler collections (Appendix 23) were dominated by Trichoptera (Hydropsyche spp.) and Plecoptera (Isogenoides sp. and Isoperla longiseta). The Diptera (including S. arcticum) were not abundant in either sample collections.

3.3 Methoxychlor Residues - Water

Residue levels of water samples collected upstream of Fort McMurray for the first and second treatments are presented in Table 5. Samples were collected on the day following the treatment at locations where the methoxychlor pulse was calculated to be.

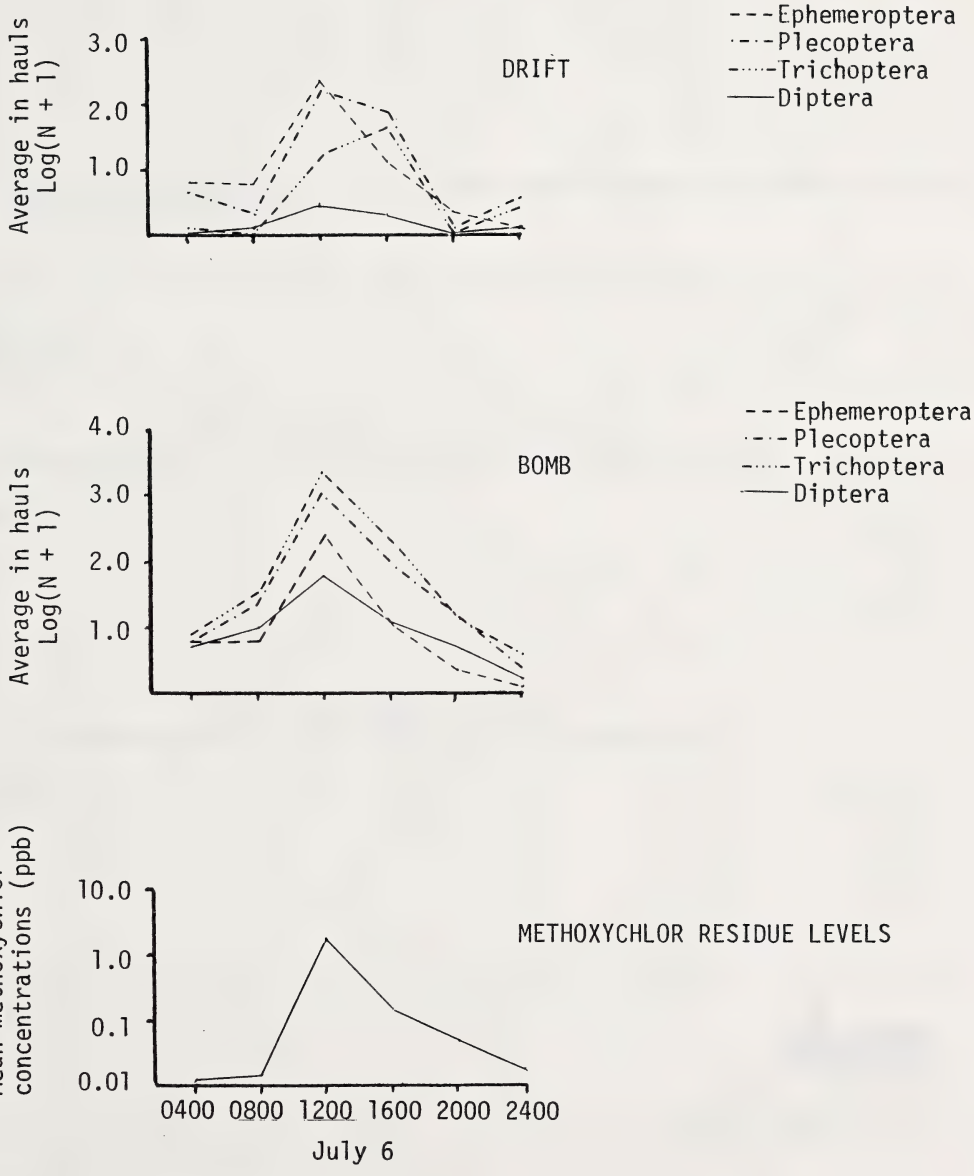

Figure 18 - Mean haul of invertebrates from drift net and bomb samples collected on July 6, 1983 at 178 km; with mean methoxychlor residue levels

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Table 5. Methoxychlor residue levels in river water samples collected one day after each treatment.

Sample locations (km d/s of Athabasca)		Residue levels (ppb)
	May 30/31 treatment at 80 and 160 km. (Sampled June 1, 19 - 19.5 hours post treatment (160 km)	
35	(check sample)	< 0.01
200		0.2
220		1.7
230		1.8
235		2.7
	July 5 treatment at 80 km (Sampled July 6, 17.5 - 18 hours post-treatment)	
22	(check sample)	< 0.01
170		0.69
175		0.76
186		0.82
193		0.17

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Higher residue levels (1.7-2.7 ppb) were found in samples collected after the first treatment than after the second one (0.17-0.82 ppb). Samples were collected only 60 - 75 km downstream of the injection point on June 1, and 90-113 km downstream on July 6. This may account for the difference in residue levels, even though they were comparable to the residue levels measured in previous years.

Water samples collected at 178 km for both treatments (Table 6) indicated that residue levels and time of passage fluctuated greatly after the first treatment. In contrast, residue levels after the second treatment showed a unimodal peak with low variation for each series of samples. This is likely related to the higher river discharge at the time of the second treatment. Residue levels after the first treatment were much higher (up to 33 ppb), because of the second injection at 160 km.

Methoxychlor residues in water as the pesticide passed by Fort McMurray and area are presented in Tables 7 and 8.

The City of Fort McMurray was warned in advance of the treatments, and shut off the river intake pumps from 2400 hours on June 2 to 1645 hours on June 3. After the second treatment, the river intake pumps were shut off from 1400 hours on July 7 to 0900 hours on July 8. Notwithstanding these precautions taken during the calculated passage of methoxychlor contaminated water, residues were still collected from the raw water reservoir. Residue levels ranged from just above the detection level of 0.02 ppb up to 0.3 ppb.

Table 6. Methoxychlor residue levels in water samples collected at 178 km following both treatments - 1983.

Date and time of sampling	Time after treatment (hours)		Sample Location			Mean Residue levels (ppb) ± std. dev.
			East Bank	Centre	West Bank	
		May 30/31 treatment				
	(a)	(b)				
May 31						
1200	(18.25)	(-2.0)	0.10	(e)	14.0	7.05 ± 9.83
1600	(22.25)	(2.0)	(d)	<0.01	<0.01	<0.01 ± 0.00
2000	(26.25)	(6.0)	33.0	(e)	(e)	33.0
2400	(30.25)	(10.0)	2.0	1.0	20.0	7.67 ± 10.69
June 1						
0400	(34.25)	(14.0)	1.0	0.20	1.0	0.73 ± 0.46
0800	(38.25)	(18.0)	(e)	<0.01	0.55	0.28 ± 0.39
1200	(42.25)	(22.0)	2.0	<0.01	0.30	0.77 ± 1.08
1600	(46.25)	(26.0)	0.20	0.20	(e)	0.20 ± 0.00
2000	(50.25)	(30.0)	0.20	<0.01	0.90	0.37 ± 0.47
2400	(54.25)	(34.0)	12.0	<0.01	<0.01	4.0 ± 6.93
		July 5 treatment				
	(c)					
July 6						
0400	(11.0)		0.03	<0.01	<0.01	0.01 ± 0.02
0800	(15.0)		<0.01	0.07	trace	0.02 ± 0.04
1200	(19.0)		2.16	1.50	3.10	2.25 ± 0.80
1600	(23.0)		0.29	0.11	0.18	0.19 ± 0.09
2000	(27.0)		0.06	0.08	0.06	0.07 ± 0.01
2400	(31.0)		0.04	0.04	0.02	0.03 ± 0.01

(a) Calculated from 80 km injection at 1745 hours on May 30.
(b) Calculated from 160 km injection at 1400 hours on May 31.
(c) Calculated from 80 km injection at 1700 hours on July 5.
(d) Sample missing.
(e) Sample destroyed in transit.

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Table 7. Methoxychlor residue levels (ppb) in water samples collected from Fort McMurray area, May 30/31 treatment.

Date and time of sampling	Time after treatment (hours)		Fort McMurray		Bridge		Syncrude		Fort MacKay Bridge	Fort Mackay Hamlet
			Reservoir	Treated Water	East Bank	West Bank	Intake	Reservoir		
June 2	(a)	(b)								
2200	(76.25)	(56.0)			0.5	1.0				
2400	(78.25)	(58.0)	(c)							
June 3										
0100	(79.25)	(59.0)			0.2	<0.01				
0500	(83.25)	(63.0)			0.6	0.8				
1000	(88.25)	(68.0)			(e)	1.0				
1200	(90.25)	(70.0)			0.8	(e)				
1300	(91.25)	(71.0)					0.2			
1500	(93.25)	(73.0)							<0.01	<0.01
1600	(94.25)	(74.0)					0.5	<0.01		
1630	(94.75)	(74.5)			0.3	0.7				
1645	(95.00)	(74.75)	(d)							
2030	(98.75)	(78.5)	<0.01		2.0	0.4				
2200	(100.25)	(80.0)					0.6	0.8	0.6	0.2
June 4										
0600	(108.25)	(88.0)	0.3	<0.01	0.1	0.15				
0700	(109.25)	(89.0)					0.5	0.1	0.4	(e)
1400	(116.25)	(96.0)	(e)	<0.01						
1500	(117.25)	(97.0)							(e)	<0.01

(a) Time calculated from 80 km injection at 1745 hours on May 30.
(b) Calculated from 160 km injection at 1400 hours on May 31.
(c) Fort McMurray river water intake pumps shut off.
(d) Fort McMurray river water intake pumps turned on.
(e) Sample destroyed in transit.

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Table 8. Methoxychlor residue levels (ppb) in water samples collected from Fort McMurray area, July 5 treatment.

Date and time of sampling	Time after treatment (hours)(a)	Fort McMurray Bridge			Syncrude Intake	Fort Mackay Bridge	Fort Mackay Hamlet
		Reservoir	East Bank	West Bank			
July 7							
1300	(44)		<0.01	Trace			
1400	(45)	(b)					
1630	(47.5)		<0.01	<0.01			
2030	(51.5)		0.75	0.82			
July 8							
0030	(55.5)		1.30	1.24			
0630	(61.5)		0.23	0.15			
0700	(62)				1.12		
0730	(62.5)					Trace	<0.01
0900	(64)	(c)					
1200	(67)	0.02					
1230	(67.5)		0.09	0.09			
1300	(68)				0.52		
1330	(68.5)						0.97
1400	(69)					0.77	
1800	(73)	0.03					
1830	(73.5)					0.33	0.56
2400	(79)					0.13	0.12
July 9							
0100	(80)	0.02					
0830	(88.5)	0.02					

(a) Calculated from 80 km injection at 1700 hours on July 5.
(b) Fort McMurray river water intake pumps shut off.
(c) Fort McMurray river water intake pumps turned on.

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Low residue levels (below 1.0 ppb) were found in river water samples collected at Fort Mackay and the Fort Mackay bridge, and just upstream, near the Syncrude water intake, levels ranged up to 1.12 ppb. However the majority of samples were 0.5 to 0.6 ppb.

Water samples were also taken on June 3 and 4 from the discharge pipe supplying the water reservoir for Syncrudes's lower camp facility, and residue levels of up to 0.8 ppb were detected. The main raw water reservoir, which supplies the oil sand extraction facility and offices at the actual mine site was not sampled.

3.4 Methoxychlor Residues - Sediment

None of the 17 sediment samples collected for residue analysis in the Delta area of Lake Athabasca had detectable residues of methoxychlor, or any of the other compounds tested for in a general pesticide scan. A list of the compounds in the pesticide scan (including detection levels) is presented in Table 9. Analysis of samples was conducted by Chemistry Wing, Alberta Environmental Centre, Vegreville.

3.5 Methoxychlor Residues in Fish

As part of a province wide sampling program, staff from the Aquatic Biology Group, Alberta Environmental Centre, Vegreville, collected a number of fish from the Athabasca River following the May 30/31 treatment (Alta. Env. Centre, 1984). A total of 48 fish were collected on the 13 and 14 of June, 1983 from four sites: Vega Ferry (204 km upstream of the Town of Athabasca), Highway 2 bridge (117 km upstream of Athabasca), the bridge at Athabasca (0 km), and the Calling River confluence (76 km downstream of Athabasca).

Table 9. List of pesticides analyzed for in sediment samples collected from the Athabasca Delta area.

COMPOUND	DETECTION LEVEL (ppb)
Aldrin	0.050
-Chlordane	0.050
-Chlordane	0.050
Captan	0.050
Dacthal (Chlorthal Methyl)	0.050
o,p' - DDD	0.050
p,p' - DDD	0.050
o,p' - DDE	
p,p' - DDE	0.050
o,p' - DDT	0.050
p,p' - DDT	0.050
Diallate (Avadex)	0.050
Dieldrin	0.050
Dursban (Lorsban, Chlorpyrifos)	0.050
-Endosulfan	0.050
-Endosulfan	0.050
Endrin	0.050
Heptachlor	0.050
Heptachlor epoxide	0.050
Hexachlorobenzene (HCB)	0.050
-Hexachlorocyclohexane	0.050
-Hexachlorocyclohexane	0.050
-Hexachlorocyclohexane	0.050
Kelthane (Dicofol)	0.050
Mirex	0.050
Perthane	0.050
Ramrod (Propachlor)	0.050
Triallate (Avadex BW)	0.050
Methoxychlor	0.010
2,4-D	0.020
2,4,5-T	0.020
Dicamba	0.020
Picloram	0.020
MCPA	0.020

Seven species of fish were collected: Rocky Mountain whitefish, longnose sucker, flathead chub, walleye, goldeye, northern pike and arctic grayling. Muscle tissue and fat from the fish were analyzed for residues of methoxychlor and its lipophilic metabolite, 2,2-bis(p-methoxyphenyl)-1,1 dichloroethylene.

No detectable residues (detection limit: 1.0 ppb) were found.

3.6 Adult Black Fly Monitoring

The results of adult black fly monitoring in the affected farming area are shown in Figures 19 to 21. Mean numbers of black flies collected by barrel traps are presented in Figure 19, by sweep nets in Figure 20, and by silhouette traps in Figure 21. Two of the sampling methods, the barrel trap and the silhouette trap (Figures 19 and 21) showed a peak in adult black fly numbers at the Mitchell farm during the week of July 19, whereas the sweep net (Figure 20) did not. In the period August 9 - 16, all three sampling methods showed a significant peak.

A major difference in the numbers of adult black flies collected is observed between the Mitchell and Lantz farms. Sampling conditions were as similar as possible, given the different layout of the two pastures. Therefore, it can be inferred that substantially more black flies were present in the Wandering River area than in the Grassland area.

The significant drop in adult numbers at the Mitchell farm between August 16 and August 23 (silhouette and barrel traps) was most likely caused by the cattle being moved to another pasture, reducing the number of adult flies in the area and emphasizing the natural decline at that time.

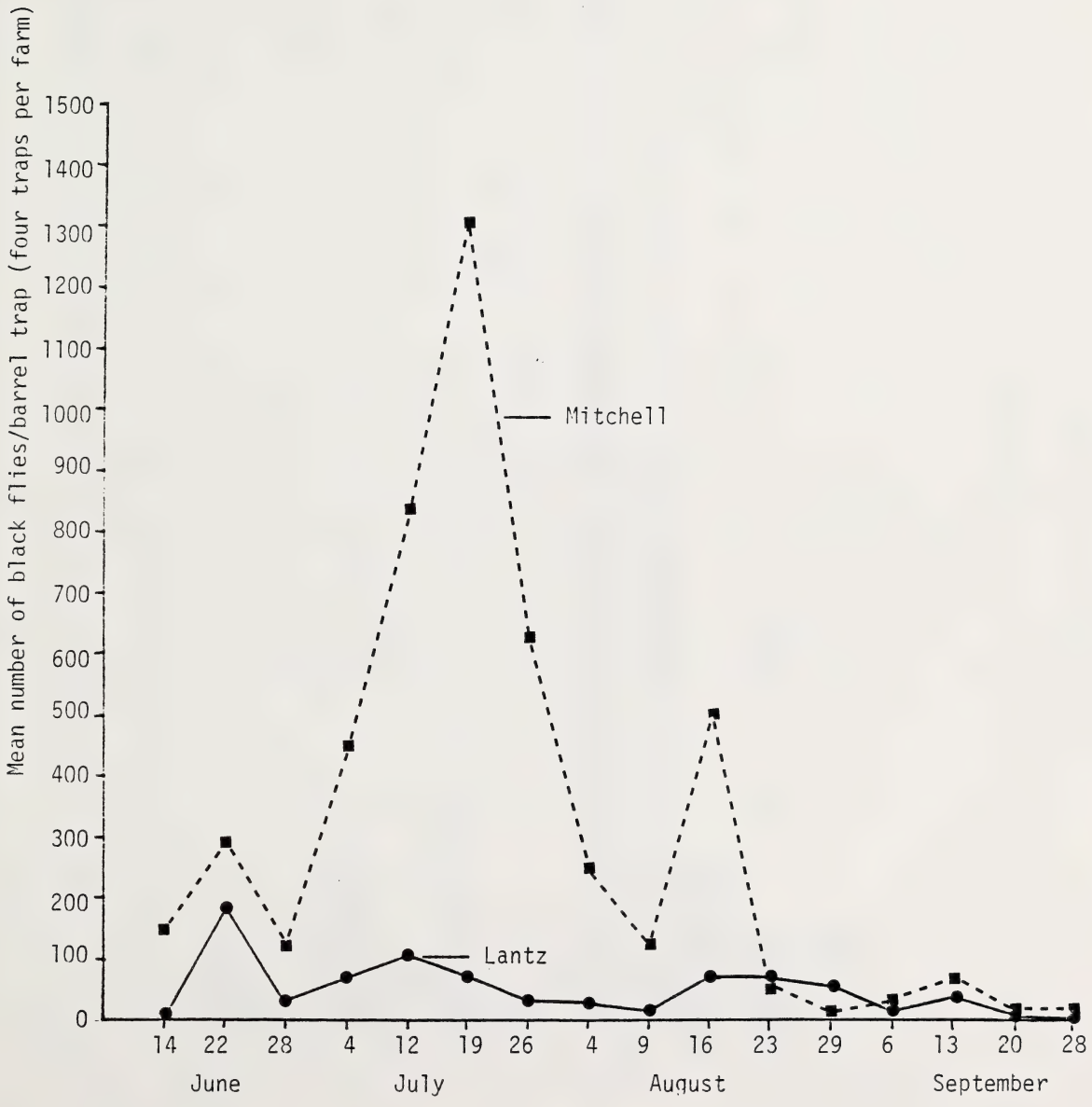

Figure 19 - Mean numbers of black flies collected on barrel traps at two locations, 1983

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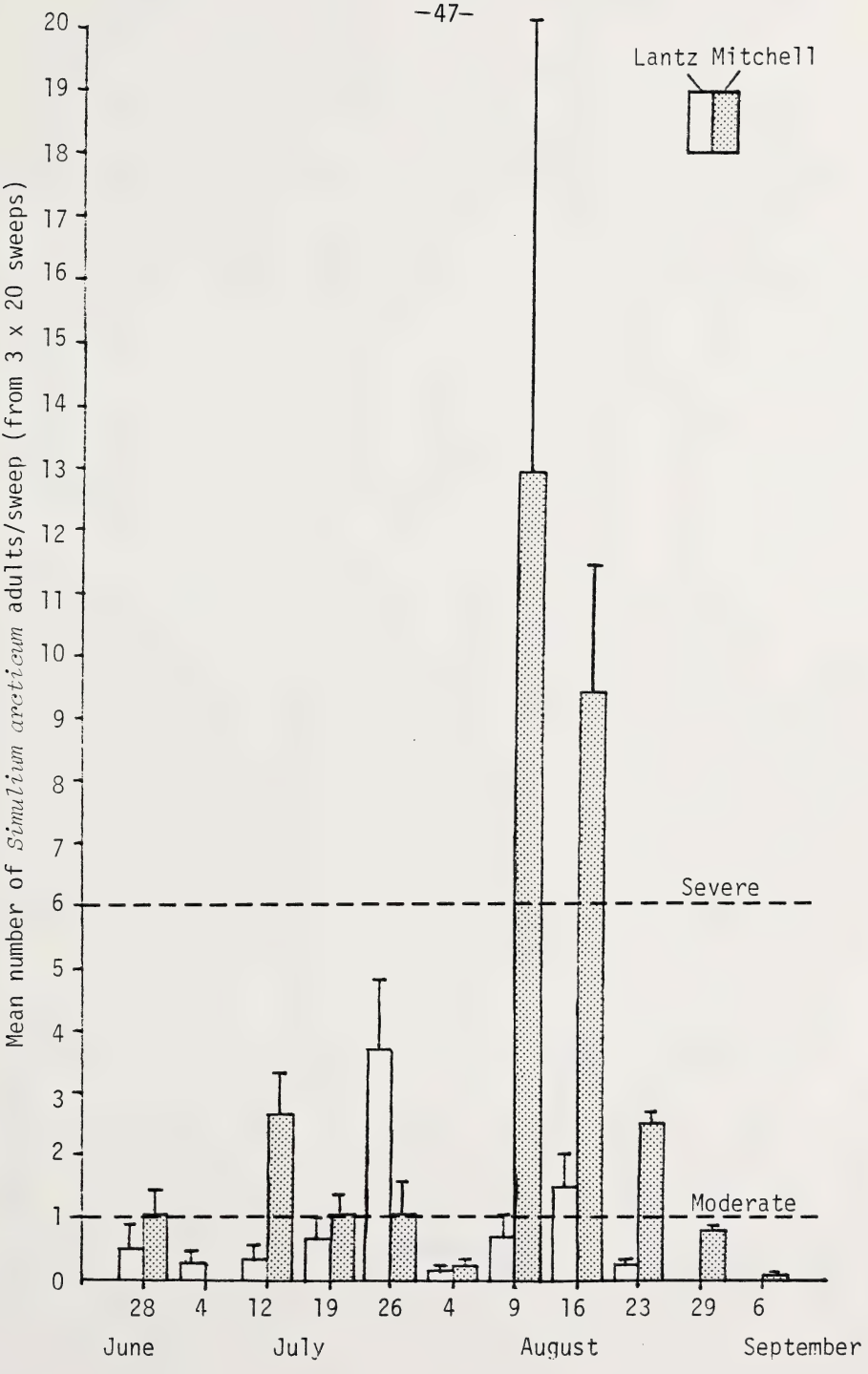

Figure 20 - Mean number of *Simulium arcticum* collected per sweep at two locations, 1983

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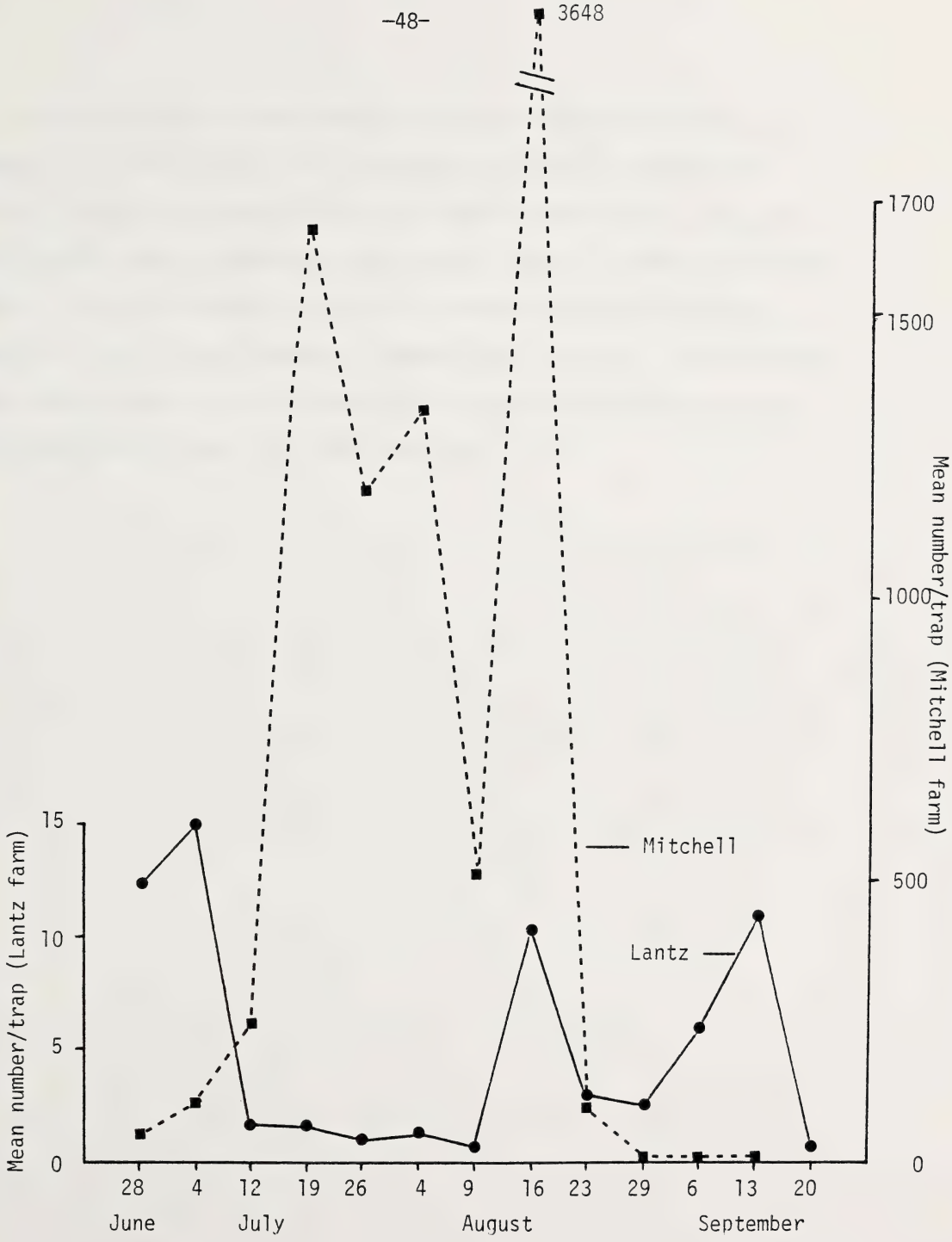

Figure 21 - Mean number of *Simulium arcticum* collected per silhouette trap at two locations, 1983 (three traps per farm)

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Figure 20 shows the mean numbers of flies collected in sweep net samples with the level of attack categories outlined by Shemanchuk (1980). Black fly numbers at Mitchell's were at the severe level only in early August and at moderate to light levels during the remainder of the summer. Black fly numbers at Lantz's remained in the light category except in late July when moderate numbers were collected. This may have been caused by two consecutive days of strong winds on July 24 and 25 which moved adult black flies into the area.

4.0 DISCUSSION

4.1 Non-target Organism Sampling

4.1.1 Bottom Samples (Rock Tumble)

Analyses of non-target organism populations revealed a number of patterns concerning the genera used as indicators of benthic community stability. Dominance and diversity indices showed that no major change in community stability occurred at any of the sites over the period studied.

Dominance indices above 0.60 (the value considered to be approaching an enriched community i.e. polluted, Wilhm, 1972) were found only at two sites during three spring sampling periods. No patterns or trends were evident to indicate anything other than natural phenological changes.

Following the high water period in July (Figure 2), the benthic community at all of the sites became very homogenous and stable, as indicated by dominance and diversity indices. It appears that peak flows have an equalizing effect on the river's macrobenthic community.

Section 3.2.1 examined the population changes of a select number of genera. Few indications of deleterious effects from the methoxychlor treatment were revealed. It is debatable whether the reduction in numbers of Baetis tricaudatus following the first treatment was caused entirely by a natural emergence. The emergence of B. tricaudatus at the end of May was documented previously (Byrtus and Jackson, 1984) and was evident in this study at the control sites.

However, it is possible that some of the population was affected by the treatment before emergence was completed (as evidenced by the large number of Ephemeroptera observed in the drift samples). The limited drift sampling program prevented determination of the fate of drifting invertebrates.

The timing of the first methoxychlor treatment may have also placed at risk the other Ephemeroptera monitored (Ephemerella inermis and Rhithrogena undulata). Both species overwinter as nymphs and emerge in spring or early summer (Edmunds et al., 1976). However, late summer samples contained high numbers of both E. inermis and R. undulata, leading to the conclusion that both species survived the treatments.

The two species of Heptagenia genera most abundant in the benthic samples should not have been affected by the methoxychlor treatments because of their hatch and emergence periods. These organisms hatch predominately in mid summer and emerge in late summer (Edmunds et al., 1976). The results from the 1983 non-target monitoring program substantiated this.

Isoperla longiseta and Isogenoides sp. emerge in early summer (Dosdall and Lehmkuhl, 1979), thus being at risk of a reduction in populations because of the methoxychlor treatment. The data suggest a drop in numbers of stoneflies in the post treatment samples, but an overall return in numbers later in the sampling period.

Populations of all the key genera returned to a typical level (in relation to previous years and control site data) after the high water period of July.

Cluster analysis of benthic data was particularily useful in detecting the effects of type of substrate, time of sampling, longitudinal succession and flooding on the macrobenthic community. Cluster analysis was not effective in measuring changes in invertebrate composition or density caused by the methoxychlor applications, possibly because of missing samples, or because the method is not sufficiently precise for the data available here.

The National Research Council (NRCC, 1983) expressed a concern that the monitoring program did not assess control and treated sites adequately before using them for post-treatment comparisons. Cluster analysis indicated that control sites 40 and 80 km were comparable to the treated sites, however, the -20 km control site was not. These discrepancies may be caused by: 1) the fact that the -20 km site is located in an ecologically different reach of river; or 2) differences in sampling crews.

4.1.2 Drift Samples

A large number of dead or moribund insects were observed drifting down the river while collecting water samples at 230 and 235 km on June 1, and again while collecting water samples on June 3 at Fort McMurray. Visibility in the river water at this time exceeded 60 cm, as opposed to the normal visibility for May/June of less than 5 cm. A 10 cm diameter dip (plankton) net, held 20 cm below the water surface nine metres from shore, collected from 2142 to 320 black fly larvae/minute. Collections were made at 1030 and 2100 hours, respectively, on June 3. The river depth was 60 cm, and the velocity was about 40 cm/second. Other invertebrates made up approximately 10% of the total number, with Plecoptera being of the greatest abundance. No estimates of invertebrate mortality were recorded.

The large numbers of Simulium arcticum observed at Fort McMurray in June drift samples indicated that the first treatment was successful in dislodging and/or killing the black fly larvae. The high proportion of S. arcticum in the drift samples indicated also that there was some selectivity to the control program in this instance. Data from Flannagan et al. (1980) indicated that S. arcticum was very abundant in drift samples from Fort McMurray. However they did not provide relative proportions of S. arcticum to other invertebrates in the samples.

One of the major shortcomings of the drift sampling program at 178 km was that the sampling period was too short. No pre-treatment sampling was conducted to determine regular drift densities or diel patterns, and sampling was not continued long enough to estimate recovery.

However, Haufe et al. (1980b) did determine that samples collected from the "upper thalweg" of the river (where our bomb samplers were located) exhibited the lowest variation with time among hauls in the cross section of the river. Samples from the "ebb current" of the river (which approximated drift net sampler locations) exhibited "behavioral drift" with a diel pattern. Peaks in numbers of organisms collected between 2000 and 0800 could reflect local behavioral activity of invertebrates in shallow shoreline locations.

The effect of the methoxychlor on aquatic invertebrates was evident in relation to the timing of the peak drift collections. The May and July bomb sampler and the July drift net peak collections coincided with the highest chemical concentrations.

The May drift net collections, however, peaked in the four hour period after the peak chemical concentration, because of lower velocity (from lower discharge) and a shoreward movement of drifting insects. This movement was observed by Lehmkuhl (1981) after methoxychlor treatment on the Saskatchewan River. He observed increased levels of insects collected in shoreline samplers compared to mid-channel samplers. He suggested that the methoxychlor dislodged organisms from mid-river fast current areas toward slower current areas near the shoreline.

Ciborowski (1983) estimated settling and lateral dispersal rates of two mayfly species in a large tributary (Pembina River) of the Athabasca River. He found that live animals settled over shorter distances and were more widely dispersed laterally than dead ones. He worked on a relatively short stretch of river (12 metres), nonetheless, the results proved that the mobility of live animals greatly increases the lateral dispersion. A theoretical possibility for our observations is that lateral dispersion of live insects upon contact with methoxychlor resulted in a slightly delayed increased density in shoreline areas.

Lehmkuhl's observation (1981) of shoreward movement correlated with our May drift samples and with visual observations made while collecting water samples further downstream. This shoreward movement was not observed in July because of higher discharge and because the velocity near the shoreline was higher in July (55 cm/sec) than in May (25-40 cm/sec). It was also not observed because of the higher turbidity. As well as being impossible to see below the surface of the water, higher turbidity is thought (Fredeen et al., 1975) to increase the specificity of methoxychlor to filter feeding simuliids because of adsorption to suspended silt particles and organic

matter. Low turbidity levels leaves methoxychlor in the water column where it is thought to injure other aquatic invertebrates (non-filter feeding) by contact. (Byrtus and Jackson, 1984).

4.2 Methoxychlor Residues - Water

The dispersion and travel of methoxychlor in river water is very dependent on river discharge (Table 6). Variable concentrations of methoxychlor were detected after the first treatment, even though a higher initial concentration was used and injection occurred at two sites (one site only 18 km upstream). The very low level of suspended sediments observed in the river for the first treatment likely influenced the dispersion of methoxychlor in the river water. Unfortunately, neither turbidity levels nor suspended sediment data were collected for future reference. Also, several samples from the first treatment were lost in transit and this compounded the variation in the sample results.

High methoxychlor residue levels were recorded on May 31 at 178 km, two hours before the methoxychlor injection at 160 km (1400 hrs). This indicated that the timing of the injections did not result in a synchronous pulse as treated water from the 80 km injection passed through before the 160 km injection proceeded. The asynchronous pulse may have been advantageous in helping to "flush" drifting black fly larvae further downstream, although the extent and importance of this "flushing" action towards an effective black fly control program is uncertain.

There is concern regarding the residue levels in water samples collected at Fort McMurray (Tables 7 and 8). Residues were entering the raw water reservoir at Fort McMurray, even though the intake pumps were shut down for 17 to 19 hours. Charnetski et al. (1980a) reported the

presence of methoxychlor in river water at Fort McMurray for 12 to 24 hours, depending on injection location. After the first treatment in 1983, methoxychlor was detected in river water at Fort McMurray for at least 32 hours; and after the second treatment, for at least 16 hours. A 48 hour shutdown period would be required to minimize the chances of methoxychlor entering the raw water reservoir. However, the capacity of the raw water reservoir limits the shutdown period to less than 24 hours, otherwise the water treatment facility would have to suspend operations.

The time of passage of methoxychlor at Fort McMurray is also influenced by the discharge and subsequent velocity of the river, and by the timing of the two injections for the May treatment. In 1983, the timing of the injections did not result in a synchronous pulse and this was reflected in the results at Fort McMurray, where a slight bimodal peak in concentrations occurred. The fact that river discharges were low for the first treatment also added to the increase in length of pesticide pulse, as slow water reaches and numerous backwaters upstream would have fragmented and extended the methoxychlor pulse. The high river discharge for the second treatment resulted in a relatively rapid passage past Fort McMurray, and this is the probable reason for the lower residue levels detected in the raw water reservoir.

No methoxychlor residues were detected in samples of treated water collected at the water treatment facility. Levels of methoxychlor in the raw water reservoir were well below the maximum acceptable levels allowed by Health and Welfare Canada (1978) of 100 ppb. However, they state:

> "It is desirable that drinking water be free of pesticides, and every effort should be made to prevent pesticide pollution of raw water sources. The specification of maximum acceptable concentrations in this document should not be interpreted as a permit to allow the degradation of drinking water supplies to the indicated limits."

As society becomes more concerned with pesticides and other contaminants in food and water supplies, the possibility that pesticides are entering the drinking water supply may be cause for concern for the residents of Fort McMurray.

One of the unknowns in this situation is the fate of methoxychlor in water that travels through the water treatment process. At Fort McMurray this includes chemical additions such as lime, soda ash, alum and coagulant aids for precipitating suspended solids, clarification to remove chemical additives and suspended material, addition of chlorine and fluorine, and final filtration before being sent through the distribution system to storage reservoirs which are located in residential areas (Stanley Associates Eng. Ltd., 1974). It is recognized that methoxychlor adsorbs to suspended silt particles (Fredeen, 1977), and has a low water solubility rate (0.1 mg/l - Gardner and Bailey, 1975); therefore, it is suspected that the majority of methoxychlor entering the water supply system is entering via suspended silt particles. Consequently, the silt particles carrying methoxychlor would be expected to precipitate out in the storage reservoir or through the water treatment process. However, this would lead to the possibility of minute amounts of methoxychlor leaching out from deposited sediments in the reservoir and causing a long-term water contamination problem. Residue analysis of sediments from the reservoir would begin to address this issue.

4.3 Methoxychlor Residues - Sediment

Residue analysis of sediment samples from the Athabasca Delta area (Section 3.4) were negative for all pesticides tested. Charnetski *et al.* (1980b) also reported no detectable levels of pesticide residues in

sediment samples collected from the Athabasca Delta area in 1977, similar to results obtained during 1982 from Tobin Lake in Saskatchewan (Sawchyn, 1983).

A major consideration when interpreting this information is the magnitude of sedimentation in the Athabasca River Delta. Neill et al. (1981) documented the sedimentation process in the Delta area and Lake Athabasca. They reported average annual sediment inflows to the lake of 8×10^6 tonnes/year. Half of this total inflow usually occurs in one month, usually June, July or August. Annual sediment outflow to the Slave River is approximately 65% of total inflow, leaving approximately 2.6×10^6 tonnes of sediment retained in the Delta each year. They were unable to find a reference in the literature dealing with a comparable situation, where inflows and outflows are close together at one end of a shallow lake and a large amount of sediments pass through the lake without settling out. With the large amount of sedimentation in the lake and Delta area, and the passage of fine suspended particles through the lake, the dilution and dispersion of any pesticide adsorbed to silt particles would make residues very difficult to find.

Another consideration in interpreting this information deals with the size ranges and physical/chemical characteristics of particles that methoxychlor adsorbs to. Charnetski and Depner (1980) recommended that "The concentration of methoxychlor on various particle size ranges should be identified together with the nature of these particles." If this information was known, selective sampling for specific size ranges of sediments would lead to a better probability of finding residues.

Other possibilities for the lack of detectable residues include the breakdown of methoxychlor to undetermined products by the time sampling is conducted, or that methoxychlor residues were deposited in pesticide "sinks" upstream of the Delta area.

4.4 Methoxychlor Residues - Fish

The lack of methoxychlor residues in fish tissue (Alberta Environmental Centre, 1984) could be caused by two factors. First, all sampling locations were upstream of the treatment point, which assumes that fish within the treated area moved upstream. Second, sampling was conducted two weeks after the treatment, which may have been a sufficient period of time to allow clearance of residues. Lockhart (1980) indicated that a period of two weeks allows clearance of most methoxychlor residues from fish tissues.

Residue analysis for methoxychlor in fish from the Athabasca River was carried out by others with various results.

Murray and Jackson (1982) reported methoxychlor residues ranging from 71-2840 ppb in fat tissue and 877 ppb in liver tissue (1 burbot) in fish collected 40 km downstream 10 days after a 1981 treatment. No residues were detected in fish collected one month following treatment.

Following the June 4, 1974 treatment, Charnetski and Currie (1980) found residues in the fat tissue of longnose sucker (179 ppb), walleye (29 ppb) and pike (9 ppb) caught between July 31 and September 19, 1974. No methoxychlor residues were found in tissues of fish collected in 1973.

Lutz and Hendzel (1977) reported on residues (whole fish composite) in fish collected in the Fort McMurray - Lake Athabasca area for the Alberta Oil Sands Environmental Research Program (AOSERP). Fish were collected four months after the treatment in 1975. Two walleye had residue levels of 19 and 27 ppb, while four suckers had residue levels ranging from 31 to 46 ppb.

The interesting point in this data is that one walleye and one sucker were collected from Richardson Lake (Figure 3), a tributary to the Athabasca River 659 km downstream from the treatment location (Canadian Hydrographic Service, 1983). The other four fish that had detectable residues were collected from the Athabasca River between Fort McMurray and Fort MacKay (55 km downstream of Fort McMurray).

Lutz and Hendzel (1977) did not attribute residues to the 1975 methoxychlor treatment. However, if the treatment was the sole source of methoxychlor in the river system, it is interesting that methoxychlor would still be detected in fish four months later at a considerable distance downstream of the treatment location. Sawchyn, (1983) in Saskatchewan found mean residue levels of 373 ppb in fat tissue of goldeye collected in the spring of 1982, ten months after the last methoxychlor treatment.

These observations are contradictory to the field observations of Lockhart (1980) and to lab observations of Reinbold et al. (1971) which indicated that methoxychlor is readily cleared from fish tissue, presumably by metabolism, over a period of two weeks.

The results raise many questions in the work done on methoxychlor residues in fish that have yet to be answered. What factors control or influence the rate of clearance (metabolism) of methoxychlor from fish? How can residue levels be maintained or increase over time (as was observed in Saskatchewan)? Also, NRCC (1983) indicated that residue levels in fish are of little value unless correlated to biological responses.

More fisheries research is required before negative impact or no impact conclusions can be drawn regarding the effect of methoxychlor residues on fish in the Athabasca River.

4.5 Adult Black Fly Sampling

The objectives of the adult black fly sampling was to correlate peaks in adult numbers with expected emergence based on larval population data and to assess the magnitude of the black fly problem in 1983. The adult samples showed two distinct peaks in numbers during the periods of July 19-26 and August 9-16. Larval black fly population data (Murray, 1984) indicated that emergences would be expected after the sampling periods of June 25/26 and July 31/August 1. Although the treatment of July 5 was apparently effective in reducing the black fly larval numbers, a large number of adults did reach the farming area. However, reports from farmers indicated that the number of black flies around their cattle was greatest in August, following the July 31/August 1 larval population which was not subjected to a treatment. Stable weather patterns in August may have also influenced adult populations around the livestock.

Given the data available, it appears that a period of two weeks is required between observing the larvae at mature instars, and arrival of adults in the farming area. This is only a rough estimate, as many biological and climatic factors influence emergence and dispersal. However, given accurate larval samples, an approximation of adult black fly arrival in the farming area can be forecast for implementation of on-farm cattle protection measures.

It was evident that the second treatment was of some value in reducing the black fly problem at the farm level when comparing larval numbers to adult numbers. The untreated August larval population, although collectively not exceeding the treatment threshold level (Figure 4), resulted in adult black fly numbers reaching the severe level at the Mitchell farm. Unfortunately, adult collection data were not obtained after the first treatment for further comparison.

The difference in the magnitude of the black fly problem in the two areas sampled was apparent in the data from 1983. Substantially more flies were collected by all three sampling methods from the Wandering River area than were collected in the Grassland area. The difference in numbers collected is extreme in the case of the silhouette traps (total S. arcticum adults collected at Mitchell's was 26,585 whereas 203 were collected at Lantz's farm) and the barrel trap samples (up to 10 times the number of flies collected at Mitchell's than at Lantz's).

The sweep samples were also considerably different between the two areas and they confirmed farmer observations of the black flies being worst during August. When the sweep numbers were compared to the black fly attack categories of Shemanchuk (1980), only at Mitchell's farm in early August was the population index over 6 black flies/sweep, which rated the severe assessment. Populations over the rest of the season at both farms rated either the light or moderate category.

Byrtus and Jackson (1984) reported that a north to south movement of adult black flies occurred in the farming area in 1982. As well, range extensions beyond the endemic problem area were reported because of the high adult black fly numbers. With the information from 1983, the theory arose that movement of black flies is from the rapids area on the Athabasca River (180 km - 396 km) to the northern edge of the farming area. Higher numbers of adults (as in 1982) disperse further south and beyond the normal ranges of the endemic problem area. This would subject the Wandering River area cattle to annual black fly problems, while cattle further south are severely affected only in outbreak years or nontreatment years.

Improvements in sampling methodology resulted in better results than were obtained in 1982 (Byrtus and Jackson, 1984). The silhouette samplers were modified slightly during the summer by changing the cone apparatus in the collecting jar from a clear acrylic to a fine mesh screen cone. Ventilation in the collecting jar improved and flies were more amenable to entering the collection jar. This increased the average collection numbers.

The differences in sampler efficiency observed in 1982 were again observed in 1983. Sweep net samples were greatly influenced by time of day and weather conditions at time of sampling, however, the specimens were the freshest and in the best condition for identification. Samples collected by silhouette trap were not greatly influenced by weather, as they were collected over a week long period. However, dehydration of specimens made identification difficult at times. Barrel traps were the easiest and quickest sampling method, but identification of specimens to the species level was impossible.

5.0 Conclusions

The Athabasca River black fly abatement program was successful in its objective of minimizing cattle harassment by adult black flies during June and July. The third population cohort of larvae, which emerged in August, was not felt to cause major distress to cattle because of the lateness of the season, the inurement of the cattle to black fly attack, and the advanced growth of the spring calf crop. It was for these reasons (and the lack of registration for a third treatment) that the third larval cohort, usually relatively low in numbers, was allowed to finish development and emerge as adults. Although the August population did reach severe levels in the Wandering River area, it was only for a short period of time.

The extent of environmental impact of the abatement program, as monitored by non-target benthic invertebrate organisms, depended on the sampling method employed. Drift sampling indicated that the methoxychlor had an acute impact on the benthos, with increases in numbers of organisms collected of up to 1000 times that of normal levels. Bottom samples did not reflect significant or long term impacts, despite extensive analysis. Without entering the acrimonious debate on interpretation of drift sampling results following methoxychlor treatments (Haufe, 1980), we can conclude only that there is a considerable gap between drift sampling results and bottom sampling results. Waters (1961), in comparing standing crop and drift of stream bottom organisms, found that distributions were not similar until the standing crop samples were qualitatively limited to groups of organisms having similar longevities.

As our experience in taxonomic identification and knowledge of life history information of benthic invertebrates from the Athabasca River increases, we may be able to make more meaningful comparisons between drift and standing crop samples in future monitoring programs.

Although no residues were detected in the City of Fort McMurray treated water supply, residues were detected in the raw water reservoir supplying the water treatment facility after both treatments in 1983. The extent of contamination was limited, with maximum residue levels of 0.3 ppb. Health and Welfare Canada (1978) have designated 100 ppb as the maximum acceptable concentration of methoxychlor in drinking water; however, they have also identified the objective concentration as being below current detection levels (0.01 ppb in this study). The residue levels involved here are very low, but as Health and Welfare Canada (1978) have stated, it is desirable that drinking water be free of pesticides. Every effort should be made to protect the City of Fort McMurray's water supply as long as methoxychlor is used for black fly control.

Extension of the river intake shutdown period would alleviate the contamination problem; however, the reservoir level would be drawn below the outflow pipe and the water treatment facility would have to suspend operations. During periods of high demand (hot, dry weather), the water treatment facility operates at a full capacity just to maintain storage reservoir levels (Gajadharsingh, 1983). Water rationing would be the next inevitable step in the process of preventing water supply contamination.

Although Charnetski et al. (1980a) did not find methoxychlor residues to be accumulating in the Lake Athabasca Delta area after four injections over three years, Haufe (1980) stated that sampling at the Delta sediments should be conducted at five year intervals as an accountability criterion for pesticide safety. Between 1979 and 1983, 14 methoxychlor injections were employed for larval black fly control.

Complying with Haufe's (1980) recommendation, our sampling after five years did not reveal any methoxychlor accumulation or contamination of the Lake Athabasca Delta. Degradation, dispersal, and deposition of methoxychlor are felt to be the probable exit routes of methoxychlor between the injection points and the Delta. Further sampling of Delta sediments for methoxychlor accumulation is not warranted unless pesticide use increases markedly.

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APPENDIX 1 - Benthic macro-invertebrates collected from the Athabasca River - May 3-6, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA						1	2	3		1	2	3								1		1		
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.																								
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus		1		1							1	1							2		2			
Centroptilum rivulare																								
Pseudocleon sp.							2	6	5		1											1		
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata							2	1	1				15	5	6									
Heptagenia diabasia																								
Heptagenia elegantula							2		1				2	2										
Heptagenia pulla				5		3	2		2	1	11	3	4	1	2				1	1				
Nixe simplicoides																								
Rhithrogena undulata	6	9	12			7	4	4	4	17	13	18	3						5	23	48	11	22	28
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei				1															1		1			
Metretopus borealis									1											1	1			
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis				4	1	10	10	25	14	6	23	4	6		7				1	6	9	5	12	7
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.				1			1	2		2	5	1	1	1	2								1	
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata										1											2	1	1	1
Nemouridae																								
Nemoura sp.	7	9	8																					
Chloroperlidae																								
Hastaperla brevis	1	1				1	1	4	1	3	1	2									6	6	6	3
Triznaka signata																								
Perlidae																								
Classenia sabulosa										1		1	2									2	3	
Acroneuria abnormis												1												
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	27	60	29	5	3	12	13	41	22	70	32	41	3	5	3				40	61	90	23	26	37
Isoperla longiseta			1	1		5	2	15	8			6	1						8	5	12	8	6	11
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																								
Cheumatopsyche spp.	10	21	15	2		2	5	6	2	1	12	13	2		4						1			
Hydropsyche spp.		2	1				8	4	2	1	4	12	2	1					1	2	3	2	4	1
Glossomatidae																								
Glossoma sp.	1											1												
Brachycentridae																								
Brachycentrus sp.				1							1								1	1	2		3	
Leptoceridae																								
Triaenodes sp.																								
DIPTERA																								
Ceratopogonidae			1																					
Chironomidae		3	4	13	7	11	23	8	8	10	12	6	6	7	5				9	26	6	21	38	23
Empididae																								
Hemerodromia sp.			3	1		1			1		2	1											2	
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum																								
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	52	106	74	35	11	53	77	119	72	114	120	114	47	22	29				69	127	183	81	124	111
TOTAL INVERTEBRATES		232			99			268			348			98						379			316	
COEFF. OF VARIATION(%)		35.1			63.8			28.9			3.0			39.5						45.1			20.9	
NO. OF TAXA	6	8	9	11	3	10	14	12	14	12	14	16	12	7	7				10	10	13	11	12	8
TOTAL TAXA		11			14			16			19			12						15			14	
DIVERSITY INDEX(d)		2.17			2.92			3.16			2.92			3.09						2.29			2.48	
DOMINANCE INDEX(s)		0.31			0.18			0.15			0.21			0.15						0.31			0.19	

APPENDIX 2 - Benthic macro-invertebrates collected from the Athabasca River - May 11-13, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA						1		2		1		2												
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.	1		1								1													
Siphlonurus sp.																								
Isonychia sp.																								
Baetidae																								
Bactis dardanus																								
Bactis tricaudatus	2									1		1		1	1								1	
Centroptilum rivulare																								
Pseudocloeon sp.							2	2	5															
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata					1								2	5										2
Heptagenia diabasia							4	2																
Heptagenia elegantula																								
Heptagenia pulla				1	1	3		1		1	2	4	2	7										1
Nixe simplicoides	5	7	8							1														
Rhithrogena undulata	14	6	2	3	9	1	5	6	3	7	24	13	1	3					7	15	28	2	9	2
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei																					1			
Metretopus borealis													1											
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.			1																					
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis	2		5	1	10	2	5	4	4	5	6	6		9	2						6	2	3	2
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.							1	1	2				1	1										
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata			2			1														1				
Nemouridae																								
Nemoura sp.	1																							
Chloroperlidae																								
Hastaperla brevis		2	1				2	1	3	1									3		2	1		2
Triznaka signata																								
Perlidae																								
Classenia sabulosa											1	1											2	4
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	89	56	29	2	21	4	28	15	27	8	20	33	1	2					17	10	34	3	12	15
Isoperla longiseta	8		2		9	2	7	6	6			2							1		2	1	1	2
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																								
Cheumatopsyche spp.		2	3		1		1	2	5		3	2		1										
Hydropsyche spp.	2		1									5		1										
Glossomatidae																								
Glossoma sp.																								
Brachycentridae																								
Brachycentrus sp.									1					1										
Leptoceridae																								
Triaenodes sp.																								
DIPTERA																								
Ceratopogonidae																								
Chironomidae	27	31	48	31	52	21	49	32	53	14	21	24	28	52	14				63	9	11	58	21	32
Empididae																								
Hemerodromia sp.					1		2		4		1												2	
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum										3	2	4	4	8	12				34	44	49	13	26	8
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	151	104	103	38	105	35	106	74	113	42	81	97	40	91	29				125	79	133	80	77	70
TOTAL INVERTEBRATES		358			178			293			220			160						337			227	
COEFF. OF VARIATION(%)		23.0			66.7			21.3			38.6			62.0						25.9			6.8	
NO. OF TAXA	10	6	12	5	9	7	11	12	11	10	10	12	8	12	4				6	5	8	7	9	10
TOTAL TAXA		14			11			14			16			13						9			12	
DIVERSITY INDEX(d)		2.14			2.02			2.50			2.78			2.14						2.19			2.17	
DOMINANCE INDEX(s)		0.33			0.38			0.28			0.19			0.38						0.26			0.31	

APPENDIX 3 - Benthic macro-invertebrates collected from the Athabasca River - May 18-21, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA				9	1	6	17	7	1	1		1												
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.																								
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus	4	6	3	1			3				1								1		2	1	2	2
Centroptilum rivulare																								
Pseudocloeon sp.								3	1															
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata				1			1					3	2	2	6								1	
Heptagenia diabasia								2	4															
Heptagenia elegantula							1																	
Heptagenia pulla				1	4	1				2	7	1		1	1				1				2	1
Nixe simplicoides	2	5								1														
Rhithrogena undulata	18	24	29	2						1	16	1			1				38	23	11		15	8
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei									1															
Metretopus borcalis																			1					
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis	8	10	2	5		1	2	2	1	9	11	1	2		3				7	7	4	5	8	3
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.		1		2		1		1	1	2	1	2			1									
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata		2	1									1							3	2			2	1
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis	2	2	5	3					1		3	1							8	7	4	1	5	1
Triznaka signata																								
Perlidae																								
Classenia sabulosa												1	1						1	1				2
Acroneuria abnormis										1														
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	91	35	50	9	3		6		2	8	12	3		1	3				12	23	14	8	10	9
Isoperla longiseta		1		2			4		3		2								2	10	6	1	6	
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																								
Cheumatopsyche spp.	5	4	6	4			1		4	1	6								2	1			1	
Hydropsyche spp.	1	2	1	1															1	1		1	1	1
Glossomatidae																								
Glossoma sp.				1																				
Brachycentridae																								
Brachycentrus sp.											1				1								1	2
Leptoceridae																								
Triaenodes sp.																								
DIPTERA																								
Ceratopogonidae			1						2		2													
Chironomidae	33	25	28	31	88	137	118	23	131	9	19	57	15	55	33				33	21	7	17	25	26
Empididae																								
Hemerodromia sp.	1							3	1	8	1				1				1	1	1	2	4	
Rhagionidae																								
Atherix sp.																			1					
Simuliidae																								
Simulium arcticum										3	5	2	2	1	4				56	50	41	6	16	8
Tipulidae	1							1																
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	166	117	126	72	96	146	153	42	163	46	87	74	22	60	54				168	147	90	42	99	64
TOTAL INVERTEBRATES		409			314			358			207			136						405			205	
COEFF. OF VARIATION(%)		19.1			36.1			56.3			30.4			45.1						29.9			42.1	
NO. OF TAXA	11	12	10	14	4	5	9	8	13	12	14	12	5	5	10				16	12	9	9	15	12
TOTAL TAXA		15			14			17			20			11						16			16	
DIVERSITY INDEX(d)		2.43			1.26			1.59			3.05			1.48						2.74			3.07	
DOMINANCE INDEX(s)		0.27			0.67			0.58			0.28			0.58						0.21			0.17	

APPENDIX 4 - Benthic macro-invertebrates collected from the Athabasca River - May 24-31, 1983 (Pre-treatment 1)

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA				2		4	3	5	7	2	13												3	2
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.																								
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus	1	1	2	5	12	6		5	4	4	5	8						3		4	1		1	
Centroptilum rivulare																								
Pseudocleon sp.									1															
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata	2	2	1	1				3	2	2	1	2	8	4	1							1		
Heptagenia diabasia							1	1	1			1												
Heptagenia elegantula									2							1	1	2						
Heptagenia pulla								1	4		1		2							1		2		
Nixe simplicoides	3																							
Rhithrogena undulata	2		3	2		1	1	1	1							6	3	12	2	2		13	25	5
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei	5	14	1																					
Metretopus borealis					1		10	11	22						5							2		
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis	1	1	4	2			4	29	13	1			1		3	44	17	14		1		5	7	
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.							1		4	2	3					2		3						1
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata		1												1										
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis		1					3	5	1							1			2	9		6	3	1
Triznaka signata																								
Perlidae																								
Classenia sabulosa																			1			2	4	1
Acroncuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.		1																						
Isogenoides sp.	11	5	30	4		1	16	61	48		4	4				14	10	22	58	143	4	12	20	9
Isoperla longiseta	2	1	3	1				22	29		1								30	57		11	12	2
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																								
Cheumatopsyche spp.		1	1	1									1											
Hydropsyche spp.																		2					1	
Glossomatidae																								
Glossoma sp.											1													
Brachycentridae																								
Brachycentrus sp.																								
Leptoceridae																								
Triaenodes sp.																				1				
DIPTERA																								
Ceratopogonidae																								
Chironomidae	163	93	23	25	24	40	22	51	30	87	63	17	34	21	37	15	12	4	16	61	81	45	28	67
Empididae																								
Hemerodromia sp.			1						1						1		3	2					3	
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum							1	3			1	1					1		6	14	6	25	64	14
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	190	121	69	43	37	52	62	198	170	98	93	33	46	26	47	83	47	64	115	293	92	124	171	102
TOTAL INVERTEBRATES		380			132			430			224			119			194			500			397	
COEFF. OF VARIATION(%)		47.9			17.2			50.1			48.4			29.9			27.8			66.0			26.6	
NO. OF TAXA	9	11	10	9	3	5	10	13	16	6	10	6	5	3	5	7	7	9	7	10	4	11	12	9
TOTAL TAXA		14			10			17			12			8			11			11			16	
DIVERSITY INDEX(d)		1.53			1.63			2.96			1.51			1.27			2.42			2.03			2.66	
DOMINANCE INDEX(s)		0.56			0.49			0.18			0.57			0.61			0.25			0.30			0.22	

APPENDIX 5 - Benthic macro-invertebrates collected from the Athabasca River - June 1-3, 1983 (Post-treatment 1)

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA										1	1		1	2	2				1				1	2
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.																								
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus											1													
Centroptilum rivulare																								
Pseudocleon sp.																								
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata											1	1							4			1	1	
Heptagenia diabasia													8	1	2									
Heptagenia elegantula													1				1	1				1		
Heptagenia pulla				3		1				2				1	1				1	1				
Nixe simplicoides																								
Rhithrogena undulata														1	1	3	4	8	11	12	21	4	1	2
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei																1								
Metretopus borealis				18	37	64	26	51	26		1	1		1							1			
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis				2	1		3		1					1		67	41	22	15	16		2	2	2
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.				1					1														1	
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata																	1							
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis																			1		5		1	
Triznaka signata																		1						
Perlidae																								
Classenia sabulosa																			1		2			
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.				3	2	1	30	1	4				2	2		1			7		17			4
Isoperla longiseta				2			35	7	6							1	2			2	1	2		
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																								
Cheumatopsyche spp.																		1	2					
Hydropsyche spp.																6								
Glossomatidae																								
Glossoma sp.																								
Brachycentridae																								
Brachycentrus sp.				1																				
Leptoceridae																								
Triaenodes sp.																								
DIPTERA																								
Ceratopogonidae																								
Chironomidae				1						5	1	2	10	17	2	3	8	11	7	36	33	28	37	45
Empididae																								
Hemerodromia sp.																								
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum				1								2								1		1	1	5
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES				32	40	66	94	59	38	8	5	6	22	26	8	82	57	44	50	68	80	39	45	60
TOTAL INVERTEBRATES					138			191			19			56			183			198			144	
COEFF. OF VARIATION(%)					38.6			44.4			24.2			50.6			31.7			22.9			22.5	
NO. OF TAXA				9	3	3	4	3	4	3	5	4	5	8	5	7	6	6	10	6	7	7	8	6
TOTAL TAXA					9			5			7			9			11			13			11	
DIVERSITY INDEX(d)					0.94			1.59			2.46			2.19			1.55			2.50			1.49	
DOMINANCE INDEX(s)					0.75			0.39			0.23			0.32			0.53			0.24			0.59	

APPENDIX 6 - Benthic macro-invertebrates collected from the Athabasca River - June 6-11, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA							9	2	2	3	1	7	1	1		5	4	3	1	1	1	3		2
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.																								
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus	8	6	13				4	14	1															
Centroptilum rivulare																								
Pseudocleon sp.																								
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata				1	1	1	5			5	5	3	2	3	7									
Heptagenia diabasia																								
Heptagenia elegantula																								
Heptagenia pulla	2	2	2				9	4			1	4	1	1		3	3			1	1			
Nixe simplicoides																								
Rhithrogena undulata	31	26	26				6	3				3				1			2	22	13	1	14	10
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei																								
Metretopus borealis				1	2	12	12	8	3	5	5			2		1								
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis	8	4	6	1			14	27	1	3	2	12	1		1	10	21	2	1	25	11	1	3	11
Tricorythidae																								
Tricorythodes minutus																1								
Caenidae																								
Caenis tardata								2																
Ephemeridae																								
Hexagenia sp.							1																	
ODONATA																								
Gomphidae																								
Ophiogomphus sp.		1	1	1			2			1	1	4					1	5			1			
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata	1	1														1				1	1		1	
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis	4	3	2	1			1	10	2			1				1	1			1			1	
Triznaka signata																								
Perlidae																								
Classenia sabulosa			1																	2				
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	120	93	72	2		3	50	62	16	1	4	5	3		2	1			1	6	3	1	2	
Isoperla longiseta	3	12	7				30	28	16	5	10	20	1			1	5	1		8	3		2	2
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																								
Cheumatopsyche spp.	8	8	8	1													1	1		1				
Hydropsyche spp.	4	1	5					2														1		
Glossomatidae																								
Glossoma sp.																								
Brachycentridae																								
Brachycentrus sp.																	1							
Leptoceridae																								
Triaenodes sp.			1																					
DIPTERA																								
Ceratopogonidae																								
Chironomidae	8	3		20	31	7	27	3	5	7	5	7	8	4	16	54	78	71	5	5	2	2	14	2
Empididae																								
Hemerodromia sp.	2	1					2			1						4	9	3		1				1
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum		1										1												
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	199	162	144	28	34	23	172	165	46	31	34	67	17	11	26	83	124	86	10	74	36	9	37	28
TOTAL INVERTEBRATES		505			85			383			132			54			293			120			74	
COEFF. OF VARIATION(%)		16.7			19.4			55.5			45.4			41.9			23.4			80.5			57.9	
NO. OF TAXA	12	14	12	8	3	4	14	12	8	9	9	11	7	5	4	12	10	7	5	12	9	6	7	6
TOTAL TAXA		16			8			16			13			8			15			13			10	
DIVERSITY INDEX(d)		2.34			1.53			3.00			3.15			2.10			1.76			2.69			2.51	
DOMINANCE INDEX(s)		0.35			0.50			0.18			0.14			0.33			0.50			0.22			0.22	

APPENDIX 7 - Benthic macro-invertebrates collected from the Athabasca River - June 14-20, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA							8		3	2	4	3			1		7	13	1		1			
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.																								
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus	3	5	7	1	2	1	5	2					1				9	1		1	1			
Centroptilum rivulare																								
Pseudocleon sp.																								
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea						1																		
Heptagenia adequata	12	3	8	1		2	4	4		5	3	5		4	5	2	10	7	1					
Heptagenia diabasia		1		2	2	2	2					1												
Heptagenia elegantula								4																
Heptagenia pulla	4	3	3			1	2	8	3	1			4	3	5	2	8	5	1					
Nixe simplicoides																								
Rhithrogena undulata	7	18	9	3		6	1		2			1				2	3			5	15	9	7	8
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei																		1						
Metretopus borealis	7	10	4	10	2	2	10	14	7	4	2	4	1					1	1					
Siphloplecton sp.	1																							
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis	11	4	6	2	1	4	12	6	17	4	1	9	4	1	1	7	21	9	9	16	29	24	21	11
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																1	1							
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.	1		1				1	2	2	1	1	1				2	3	2		1	2			
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata																	3							1
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis	5	5	7	3	3	4	7		7											3	3			
Triznaka signata																								
Perlidae																								
Classenia sabulosa												1					1							
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	27	23	36	2		4	28	17	12	1	5	4	5		6				3	4	9	2		3
Isoperla longiseta	73	65	46			1	5	9	20	26	11	20	4	3	6	9	20	5	1	4	4		1	
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																	1							
Cheumatopsyche spp.	1	1	2	1								1					11	1	2	21	40	2		2
Hydropsyche spp.	1		1						1										1	16	11	2	1	
Glossomatidae																								
Glossoma sp.																				3	2			
Brachycentridae																								
Brachycentrus sp.																2	33	20				60	104	57
Leptoceridae																								
Triaenodes sp.															2				1	1	2			
DIPTERA																								
Ceratopogonidae	1									1				1		1	1							
Chironomidae	21	8	7	25	20	43	19	22	21	13	20	108	57	72	51	124	140	148	43	12	39	36	57	49
Empididae																								
Hemerodromia sp.	1					1						4	1			1		3			1			1
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum											1	2				4	8	3	11	6	28	3	1	
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	176	146	137	50	30	72	104	88	95	58	48	164	77	84	77	157	280	219	75	93	187	138	192	132
TOTAL INVERTEBRATES		459			152			287			270			238			656			355			462	
COEFF. OF VARIATION(%)		13.3			41.5			8.4			71.4			5.1			28.1			50.8			21.5	
NO. OF TAXA	16	12	13	10	6	13	13	10	11	10	9	14	8	6	8	12	17	14	12	13	15	8	7	8
TOTAL TAXA		17			14			15			16			12			20			18			11	
DIVERSITY INDEX(d)		2.83			2.33			3.23			2.33			1.49			2.30			3.10			1.92	
DOMINANCE INDEX(s)		0.22			0.36			0.13			0.33			0.58			0.41			0.15			0.34	

APPENDIX 8 - Benthic macro-invertebrates collected from the Athabasca River - June 24-26, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA												1		1					2					1
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.																								
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus				8	6		15	21	29	21	11	68	4	3	2				14	27	11	4	3	3
Centroptilum rivulare					1																			
Pseudocloeon sp.																						1		
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea						1																		
Heptagenia adequata							1	1	4	6	1	11	2						5	6	3	3		
Heptagenia diabasia					2	2	1				1			1					2	1	4		1	
Heptagenia elegantula								2	2													1		
Heptagenia pulla							1	4	2			2	2								1			1
Nixe simplicoides																								
Rhithrogena undulata				2							2	2		1					2			1		
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei																								
Metretopus borcalis				2		2	11	3	14	3	3	5							1	3	1	1		
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis					1	1	1		1	1	3	4							4	1	1	5	2	
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.										1	2													
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata												1												
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis																								
Triznaka signata																								
Perlidae																								
Classenia sabulosa										1														1
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.				7	4	2	3	6	8	8	6	12	1						23	17	6	5	3	2
Isoperla longiseta				1			2	10	9	12	6	22	2	2	1				11	8	3	6	6	8
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																								
Cheumatopsyche spp.							1	1	1										9	4		1	2	
Hydropsyche spp.						1													3	4		6		1
Glossomatidae																								
Glossoma sp.																								
Brachycentridae																								
Brachycentrus sp.																			1			4		
Leptoceridae																								
Triaenodes sp.																								
DIPTERA																								
Ceratopogonidae										1	1													
Chironomidae				7	2	1	3	26	16	1	1			6	8				58	26	7	36	28	8
Empididae																								
Hemerodromia sp.				1				1		8	16	4							4					
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum							2	5		1									14	5	27	38	22	6
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES				28	16	10	41	80	86	64	53	131	11	14	11				153	103	64	112	67	31
TOTAL INVERTEBRATES					54			207			248			36						320			210	
COEFF. OF VARIATION(%)					50.9			35.4			51.1			14.4						41.8			58.0	
NO. OF TAXA				7	6	7	11	11	10	12	12	11	5	6	3				15	12	10	14	8	9
TOTAL TAXA					12			13			17			9						17			18	
DIVERSITY INDEX(d)					2.89			2.86			2.75			2.47						3.09			2.70	
DOMINANCE INDEX(s)					0.17			0.18			0.22			0.24						0.16			0.23	

APPENDIX 9 - Benthic macro-invertebrates collected from the Athabasca River - July 5-6, 1983 (Pre-treatment 2)

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA								1	2															
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.																								
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus							19	11	18											5	4	6	1	4
Centroptilum rivulare																								
Pseudocleon sp.																								
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata							3	2											1		1	31	3	5
Heptagenia diabasia																						1		
Heptagenia elegantula								3																3
Heptagenia pulla							1	4	1													1		1
Nixe simplicoides																								
Rhithrogena undulata							1																2	2
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei																								
Metretopus borealis							3	6	7															
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis							1	1	1															
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.																								
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata																								
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis																								
Triznaka signata																								
Perlidae																								
Classenia sabulosa																								
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.							7	5	14															
Isoperla longiseta							9	14	8											3				2
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																								
Cheumatopsyche spp.																								
Hydropsyche spp.																								
Glossomatidae																								
Glossoma sp.																								
Brachycentridae																								
Brachycentrus sp.																								
Leptoceridae																								
Triaenodes sp.																								
DIPTERA																								
Ceratopogonidae																			1	3	3			
Chironomidae							9		2										4	5	1	5	1	5
Empididae																								
Hemerodromia sp.																								1
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum							1	1	3													3		3
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES							54	48	56										6	16	9	47	7	26
TOTAL INVERTEBRATES								158												31			80	
COEFF. OF VARIATION(%)								7.9												49.8			75.0	
NO. OF TAXA							10	10	9										3	4	4	6	4	10
TOTAL TAXA								12												5			10	
DIVERSITY INDEX(d)								2.88												2.11			2.47	
DOMINANCE INDEX(s)								0.19												0.25			0.29	

APPENDIX 10 - Benthic macro-invertebrates collected from the Athabasca River - July 8-13, 1983 (Post-treatment 2)

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA							3																	1
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.																								
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus							1	6	17							3	1	2				1	2	2
Centroptilum rivulare																								
Pseudocleon sp.																						1		
Heptageniidae																								
Epeorus ironodes																		1						
Epeorus vitrea																								
Heptagenia adequata							6		3							5	2	2	1	1		3	5	6
Heptagenia diabasia																3	5	2				1		
Heptagenia elegantula									1															
Heptagenia pulla							6		3							2	2	2					3	3
Nixe simplicoides																								
Rhithrogena undulata							6		4										2			5	3	5
Stenonoma terminatum																								
Ametropodidae																								
Ametropus neavei																								
Metretopus borealis							1		5													1	1	
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis							2		1							2	2	8	6		6	9	5	6
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.																1		1						
ODONATA																								
Gomphidae																								
Ophiogomphus sp.																2						1	1	
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata																	1		1	1	1			
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis																							1	
Triznaka signata																								
Perlidae																								
Classenia sabulosa																1			1			1		
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.							24	3	14									1	2	1	1	5	5	11
Isoperla longiseta							10	3	11							28	17	11	1		3	6	6	5
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																								
Cheumatopsyche spp.																			3		2	5	12	1
Hydropsyche spp.																26	5	12	36	11	19	16	30	6
Glossomatidae																								
Glossoma sp.							1																	
Brachycentridae																								
Brachycentrus sp.																			1			3	6	
Leptoceridae																								
Triaenodes sp.																								
DIPTERA																								
Ceratopogonidae																								
Chironomidae							5	3	4							1	6	4	1			12	8	7
Empididae																								
Hemerodromia sp.																								1
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum								1															1	3
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES							65	16	63							74	41	46	55	14	32	70	89	57
TOTAL INVERTEBRATES								144									161			101			216	
COEFF. OF VARIATION(%)								58.0									33.1			61.0			22.3	
NO. OF TAXA							11	5	10							11	9	11	11	4	6	15	15	13
TOTAL TAXA								13									14			11			20	
DIVERSITY INDEX(d)								3.06									2.76			1.92			3.56	
DOMINANCE INDEX(s)								0.16									0.21			0.45			0.12	

APPENDIX 11 - Benthic macro-invertebrates collected from the Athabasca River - July 14 - 22, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA																		5	1		2			1
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Amelotus sp.																								
Siphlonurus sp.																								
Isonychia sp.																		1						
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus	4		1													3	2	3						1
Centroptilum rivulare																								
Pseudocleon sp.																				1				
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata	1															2	10	15		2	2	4	8	2
Heptagenia diabasia																				1				
Heptagenia elegantula																								
Heptagenia pulla	6	2	2													2	6	7	1				1	2
Nixe simplicoides																								
Rhithrogena undulata	6	2	3																		2		5	1
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei																								
Metretopus borcalis																								
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis	1	4	2													1	2	2						
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.																1								
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata																2								
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis			1																					
Triznaka signata																								
Perlidae																								
Classenia sabulosa	1	1	4														1							
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	35	20	17																	1		1	1	
Isoperla longiseta	14	24	16													8	41	31			1	2		
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																								
Cheumatopsyche spp.	5	3	12																1					
Hydropsyche spp.	25	38	27													5	14	10	2			1		
Glossomatidae																								
Glossoma sp.																								
Brachycentridae																								
Brachycentrus sp.																					1	1		
Leptoceridae																								
Triaenodes sp.																	1							
DIPTERA																								
Ceratopogonidae																								
Chironomidae	1	6	4													13	5	17		3		3	5	2
Empididae																								
Hemerodromia sp.																						2		1
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum																2	2	18	9	4	32	3		
Tipulidae																	2							
COLEOPTERA																								
Elmidae	1																							
NO. OF INVERTEBRATES	99	100	89													39	86	109	14	12	40	17	20	10
TOTAL INVERTEBRATES		288															234			66			47	
COEFF. OF VARIATION(%)		6.3															45.7			71.0			32.7	
NO. OF TAXA	12	9	11													10	11	10	5	6	6	8	5	7
TOTAL TAXA		13															15			13			12	
DIVERSITY INDEX(d)		2.68															2.90			1.97			3.00	
DOMINANCE INDEX(s)		0.21															0.18			0.48			0.17	

APPENDIX 12 - Benthic macro-invertebrates collected from the Athabasca River - July 31 - August 3, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA																4			5			2	6	1
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																		2						
Isonychia sp.		1																						
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus		2	2													24	24	20					1	1
Centroptilum rivulare																								
Pseudocleon sp.																			3			1		
Heptageniidae																								
Epeorus ironodes																		1						
Epeorus vitrea																								
Heptagenia adequata	5	2	2													10	8	18	5	2	13	8	4	6
Heptagenia diabasia																								
Heptagenia elegantula																								
Heptagenia pulla	15	9	7													5	3	8					1	
Nixe simplicoides																								
Rhithrogena undulata			3													1	3	5	3	1				
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei																						1		
Metretopus borealis																								
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis	1																		1		1			
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																	1							
Ephemeridae																								
Hexagenia sp.																	1							
ODONATA																								
Gomphidae																								
Ophiogomphus sp.	1																1	2						
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata		4															1							
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis																								
Triznaka signata																								
Perlidae																								
Classenia sabulosa	2	1	1																					
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	47	36	33													1		1			1		1	
Isoperla longiseta																4	8	2						
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.		1																1						
Cheumatopsyche spp.	10	30	19													20	10	24						
Hydropsyche spp.	190	233	216													23	18	34	8	10	12		3	
Glossomatidae																								
Glossoma sp.																								
Brachycentridae																								
Brachycentrus sp.	2	5	1																26	21	16			
Leptoceridae																								
Triaenodes sp.																								
DIPTERA																								
Ceratopogonidae																								
Chironomidae	5	4	10													17	11	9	6	2	3	2	10	5
Empididae																								
Hemerodromia sp.																		1					1	
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum																6	1	2				2	11	11
Tipulidae																	1			1	2			
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	278	328	294													115	91	130	57	37	48	16	38	24
TOTAL INVERTEBRATES		900															336			142			78	
COEFF. OF VARIATION(%)		8.5															17.6			21.1			42.8	
NO. OF TAXA	10	12	10													11	14	15	8	6	7	6	9	5
TOTAL TAXA		15															20			10			11	
DIVERSITY INDEX(d)		1.58															3.15			2.37			2.57	
DOMINANCE INDEX(s)		0.53															0.15			0.27			0.21	

APPENDIX 13 - Benthic macro-invertebrates collected from the Athabasca River - August 8 - 10, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA					3		1	3			3	1	2	1		4			1	2				
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.	1		2														2							
Baetidae																								
Bactis dardanus																								
Bactis tricaudatus	4	2	9	1	1		11	2		15	2	5	6	7		53	41	20		1	2	2	10	2
Centroptilum rivulare																								
Pseudocloeon sp.						1					1	4	5	4	2								7	
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata	11	17	20	3	4		2	1		1	1	2		2	1	4	12	9			2	4	4	2
Heptagenia diabasia													2			2	3	1						
Heptagenia elegantula										2														
Heptagenia pulla	6	12	16	1	1		6	8	1	2			7	4	1	28	53	39			3	4	8	3
Nixe simplicoides																								
Rhithrogena undulata	4	2	9	2	2			1					2		1	9	7	9	1	1	7	9	10	5
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei																								
Metretopus borealis										2										1	1			
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis				1						1								1	1				2	1
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																2		1						
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.	2	1								3		1	1			3	5	6		1	1	1		2
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata		1	1													2	1	3				1	1	
Nemouridae																								
Nemoura sp.																1								
Chloroperlidae																								
Hastaperla brevis																								
Triznaka signata																								
Perlidae																								
Classenia sabulosa		1																						
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	43	36	51							1		2	4	1		4	7	8				9	4	
Isoperla longiseta																	1					1		
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																								
Cheumatopsyche spp.	48	46	77	7	3		45	13		41	11	15	11	23	1	89	89	62				2		
Hydropsyche spp.	180	123	226	20	15	3	21	4		25	15	26	7	9	5	79	96	71	4	4	28	94	33	9
Glossomatidae																								
Glossoma sp.																								
Brachycentridae																								
Brachycentrus sp.				2			2		2							3	5	10			1	10		
Leptoceridae																								
Triaenodes sp.																								
DIPTERA																								
Ceratopogonidae																								
Chironomidae	14	27	5	7	10	2	61	53	2	5	2	5	4	5	2	75	23	12	4		17	20	16	18
Empididae																								
Hemerodromia sp.											1					2						2		
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum				1													1	1	1	1	1	5	1	
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	313	268	416	45	39	6	149	85	5	98	36	61	51	56	13	360	344	255	12	11	63	164	96	42
TOTAL INVERTEBRATES	997			90			239			195			120			959			86			302		
COEFF. OF VARIATION(%)	22.8			70.0			90.3			48.0			58.8			17.7			103.7			60.7		
NO. OF TAXA	10	11	10	10	8	3	8	8	3	11	8	9	11	9	7	16	14	16	6	7	10	14	11	8
TOTAL TAXA	12			12			9			14			12			20			12			16		
DIVERSITY INDEX(d)	2.15			2.58			2.14			2.51			2.97			2.92			2.57			2.74		
DOMINANCE INDEX(s)	0.33			0.25			0.31			0.25			0.16			0.17			0.25			0.25		

APPENDIX 14 - Benthic macro-invertebrates collected from the Athabasca River - August 17 - 19, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA		1		4			1		3	2	2	1		1			1	2		2		1	1	
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.																								
Baetidae																								
Baetis dardanus			3																					
Baetis tricaudatus	13	11	8			3	1	2	3	23	11	20	3	2		118	45	26		1	1	17	10	12
Centroptilum rivulare																								
Pseudocleon sp.				1						7		10		2										
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata	9	9	13			3	5	11	3	8	6	1			7	8	3	5	2	14	1	5	2	6
Heptagenia diabasia												1	5		4	2	3	1		1				
Heptagenia elegantula																								
Heptagenia pulla	10	10	12	4	11	5	10	12	10	25	16	33	2	2		47	24	22		4		4	3	5
Nixe simplicoides																								
Rhithrogena undulata		1	2				10	22	14	1			2			18	54	22	3	12	17	23	42	16
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei																								
Metretopus borealis																					1			1
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis										2						1			1	1		1		
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata		1																						
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.	1	1		1	2					1		1	3		2	5	4	5	2	6	1	1	1	2
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata	1	1							1									1		1				
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis																								
Triznaka signata																								
Perlidae																								
Classenia sabulosa	1								1															
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	28	45	21	5	6	4				15		14			1	15	21	14	2	9	9	6	29	6
Isoperla longiseta					3	4																1	1	
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																		2						
Cheumatopsyche spp.	49	159	28	16	92	18	48	55	91	98	8	114	7	1	14	192	120	286	1	20	16	13	24	22
Hydropsyche spp.	39	43	6	14	64	51	7	18	33	39	16	67	4	3	14	116	128	136	12	80	63	105	96	49
Glossomatidae																								
Glossoma sp.																								
Brachycentridae																								
Brachycentrus sp.	1	3	1		1	5		1	3							11	5	8		2	7	8	3	3
Leptoceridae																								
Triaenodes sp.																								
DIPTERA																								
Ceratopogonidae																								
Chironomidae	13	24	18	17	15	21	8	7	5	13	19	29	17	29	8	25	21	16	6	37	18	25	19	28
Empididae																								
Hemerodromia sp.	2	5	2			1					1				2	3		6		7	6	9	4	5
Rhagionidae																								
Atherix sp.																						2		
Simuliidae																								
Simulium arcticum																			1		1			1
Tipulidae									1															
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	167	314	114	62	194	115	90	128	168	234	79	291	43	40	52	561	429	552	30	197	141	221	235	156
TOTAL INVERTEBRATES		595			371			386			604			135			1542			368			612	
COEFF. OF VARIATION(%)		52.5			53.7			30.3			54.5			13.9			14.3			69.3			20.7	
NO. OF TAXA	12	14	11	8	8	10	8	8	12	12	8	11	8	7	8	13	12	15	9	15	12	15	13	13
TOTAL TAXA		16			13			12			14			13			16			17			17	
DIVERSITY INDEX(d)		2.68			2.36			2.30			2.71			2.73			2.58			2.76			2.81	
DOMINANCE INDEX(s)		0.22			0.26			0.30			0.21			0.22			0.24			0.23			0.22	

APPENDIX 15 - Benthic macro-invertebrates collected from the Athabasca River - August 24 - 26, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA			1		2	1					1	1	2	1		2		1			2			
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.	1																							
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus	13	12	10		2		2	10	4		10	9		2	2	37	19	21		5	2	9	8	6
Centroptilum rivulare																								
Pseudocleon sp.											1									1	1			
Heptageniidae																								
Epcorus ironodes																								
Epcorus vitrea																								
Heptagenia adequata	7	12	14	4	5	8	14	4	26	9	3	4	1			8	9	8	7	1	1		1	
Heptagenia diabasia										2			3	6	6									
Heptagenia elegantula																								
Heptagenia pulla	10	16	21	3	5	8	19	11	23	25	26	36	17	18	8	166	30	21	7	3	3	6	31	2
Nixe simplicoides																								
Rhithrogena undulata	15	19	9				21	10	26		2	2	2	14	6	14	12	9	4	13	22	48	46	17
Stenonema terminatum																		1						
Ametropodidae																								
Ametropus neavei																								
Metretopus borcalis								1			2								1		1			
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.																								
Paraleptophlebia sp.																2	1							
Ephemerellidae																								
Ephemerella inermis											2					1			2					
Tricorythidae																								
Tricorythodes minutus																								
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.	3	3	1	3						1	2		6	9	1	5	10	10	4	1	1	2	1	3
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata	1	1	1				2	4	3							2		3	3	2	1	1	1	9
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis																								
Triznaka signata																								
Perlidae																								
Classenia sabulosa		1	1																					
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	50	59	43	9	11	18				17	19	22	13	8	1	14	13	18	15	9	17	20	7	4
Isoperla longiseta				5	4	5																		
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																	1			1				3
Cheumatopsyche spp.	390	586	270	33	43	31	192	98	36	191	340	281	13	23	4	190	149	330	41	74	39	53	110	64
Hydropsyche spp.	248	211	198	22	17	28	65	52	24	126	94	153	7	12	12	35	44	104	34	121	106	126	186	176
Glossomatidae																								
Glossoma sp.																								
Brachycentridae																								
Brachycentrus sp.	7		3				10	2	2					2	2	9	11	22	8	4	8	15	19	7
Leptoceridae																								
Triaenodes sp.																1								
DIPTERA																								
Ceratopogonidae																								
Chironomidae	14	7	7	13	6	11	14	24	9	20	14	7	5	11	17	18	8	6	27	34	28	11	16	8
Empididae																								
Hemerodromia sp.			4		1					8	16	4	1	8	2	9		3	4	2	6	12	11	6
Rhagionidae																								
Atherix sp.																								
Simuliidae																								
Simulium arcticum										1											2		1	2
Tipulidae																		1						
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	759	927	583	92	96	110	339	216	153	400	532	519	70	114	61	513	307	558	157	271	240	303	438	308
TOTAL INVERTEBRATES	2269			298			708			1451			245			1378			668			1049		
COEFF. OF VARIATION(%)	22.7			9.5			40.1			39.6			34.7			29.1			26.5			21.9		
NO. OF TAXA	12	11	14	8	10	8	9	10	9	10	14	10	11	12	11	16	12	15	13	14	16	11	13	13
TOTAL TAXA	15			11			10			16			13			19			18			14		
DIVERSITY INDEX(d)	1.80			2.61			2.38			1.93			3.32			2.50			2.67			2.45		
DOMINANCE INDEX(s)	0.39			0.21			0.27			0.39			0.12			0.28			0.23			0.28		

APPENDIX 16 - Benthic macro-invertebrates collected from the Athabasca River - August 30 - 31, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA				11	10			4			1		22	4	5			6	5		1	2		
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.				1	4				1							1								
Baetidae																								
Baetis dardanus																1								
Baetis tricaudatus	5	2			1		9	3	5	7	4	5	8	1	2	40	9	7	5	3	1	5	13	4
Centroptilum rivulare	2		4				1																	
Pseudocloeon sp.									1	1														
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata	9	6	7	5	20	2	5	4	4	19	11	18	1			10	11	22	4	3	4	9	3	5
Heptagenia diabasia								4	1	1							1						3	1
Heptagenia elegantula											1													
Heptagenia pulla	18	17	21	71	100	5	56	55	33	50	20	43	4	1	2	76	56	77	36	7	19	25	31	18
Nixe simplicoides																								
Rhithrogena undulata	5	12	7	23	30	3	21	10	24	19	10	14	33	9	8	27	18	22	11	1	6	16	82	75
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei									1														1	
Metretopus borealis																								
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.									1									1	3					
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis					1			2	1		3					4	1	2			1	2		
Tricorythidae																								
Tricorythodes minutus							3	2										1	5	1				
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.					1				1										2	1				
ODONATA																								
Gomphidae																								
Ophiogomphus sp.	4	4	6	11	15	4	19	14	11	18	15	22				2	8	10	20	15	8	2	4	7
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata		1	2	1						5	4	1		1		1	2		3		1	4	2	4
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis																				1		3		2
Triznaka signata																								
Perlidae																								
Classenia sabulosa			1																					
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	30	38	38	30	40	11	48	35	51	49	24	32	14	18	20	14	9	5	22	9	12	3	10	13
Isoperla longiseta																1								
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																								
Cheumatopsyche spp.	139	331	345	462	532	341	310	285	235	222	222	241	39	22	33	187	81	37	67	73	20	28	73	101
Hydropsyche spp.	69	69	78	30	26	18	22	19	17	87	76	64	35	14	9	31	11	14	9	17	4	10	91	252
Glossomatidae																								
Glossoma sp.																							1	
Brachycentridae																								
Brachycentrus sp.	7	3	4	2	1		1	1	1	6		4	1	1	1	10	10	1	20	1	1	5	12	8
Leptoceridae																								
Triaenodes sp.					1														2		1	1		
DIPTERA																								
Ceratopogonidae																								
Chironomidae	3		4	13	17		6	4	4	14	2	7	6	4	1	4	5	14	11	5	1	7	4	3
Empididae																								
Hemerodromia sp.		2		3	1		1	2		6	8	1	7			3	2	19	14	5	1	32	5	9
Rhagionidae																								
Atherix sp.								1			1											1		
Simuliidae																								
Simulium arcticum																								
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	291	485	517	663	800	384	502	445	392	504	402	452	170	75	81	412	224	238	239	142	81	155	335	502
TOTAL INVERTEBRATES	1293			1847			1339			1358			326			874			462			992		
COEFF. OF VARIATION(%)	28.4			34.4			12.3			11.3			49.0			35.9			51.7			52.5		
NO. OF TAXA	11	11	12	13	16	7	13	16	17	14	15	12	11	10	9	16	14	15	17	14	15	17	15	14
TOTAL TAXA	14			17			22			18			12			20			19			20		
DIVERSITY INDEX(d)	1.85			1.64			2.07			2.44			2.80			2.92			2.28			2.80		
DOMINANCE INDEX(s)	0.43			0.54			0.41			0.30			0.18			0.20			0.20			0.21		

APPENDIX 17 - Benthic macro-invertebrates collected from the Athabasca River - September 7 - 8, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA				4	1	5	3		8	4		1	27	4		1	11		10	4			1	
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.					1																			
Siphlonurus sp.	2	2	7																					
Isonychia sp.																								
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus		1	3	1	1		5	1					1			3				9	2	1		3
Centroptilum rivulare										6			1	1		1	1							
Pseudocleon sp.													2											
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata	9	24	40	15	21	20	6			13	4	16	1	4	1	20	17	8	11	10	3	3	1	4
Heptagenia diabasia	3	1	3		3		2	2		1						5	1	1			1			
Heptagenia elegantula																		1						
Heptagenia pulla	6	33	57	36	44	51	116	46		31	14	26	4	5		91	81	56	33	29	27	25	15	25
Nixe simplicoides																								
Rhithrogena undulata			8	2	3	1	29	1	2		1					7	5	14	14	5	78	36	28	47
Stenonoma terminatum																								
Ametropodidae																								
Ametropus neavei				63			2	1	9	1			1							1	1			
Metretopus borealis																								
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.				3						1						2				2				
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis																	1	1	3		3	5	4	2
Tricorythidae																								
Tricorythodes minutus	1			1				1		3	2		3			4				1				
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.	3	1	3	5	7	13	17	8	3	26	2	26	1	1	1	9	22	17	10	17	8	1	3	6
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata			3		3	1						3				5			3	4	3		6	5
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis																								
Triznaka signata																								
Perlidae																								
Classenia sabulosa			1																					
Acroneuria abnormis																								
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	13	40	46	9	12	15	46	31	8	5	12	22	6	13	28	6	15	19	34	28	74	18	37	40
Isoperla longiseta							1																	
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																		2						
Cheumatopsyche spp.	11	51	79	3	129	167	258	13	17			118	6	6	38	41	125	105	46	28	44	56	74	40
Hydropsyche spp.			3		2	3	12		12		1				1	6	7	11	8	2	10	15	167	105
Glossomatidae																								
Glossoma sp.												1					1					1		
Brachycentridae																								
Brachycentrus sp.	1	3	1			3								1		6	17	6	3	4	17	15	36	24
Leptoceridae																								
Triaenodes sp.																								
DIPTERA																								
Ceratopogonidae																								
Chironomidae	4	4	8	22	10	25	9		13	31	9	3	4	3		10	30	26	13	25	4	8	8	2
Empididae																								
Hemerodromia sp.	1	4	8			4	2			4	12	4		1	2	2	20	45	5	33		45	74	11
Rhagionidae																								
Atherix sp.		1									1												1	2
Simuliidae																								
Simulium arcticum																								
Tipulidae						1																		
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	54	165	270	164	237	309	508	104	72	126	58	220	57	39	71	219	354	312	193	202	275	229	455	316
TOTAL INVERTEBRATES	489			710			684			404			167			885			670			1000		
COEFF. OF VARIATION(%)	66.3			30.6			106.6			60.4			28.8			23.4			20.1			34.2		
NO. OF TAXA	11	12	15	12	13	13	14	9	8	12	20	10	12	10	6	17	15	14	13	16	14	13	14	14
TOTAL TAXA	17			19			15			18			15			21			18			16		
DIVERSITY INDEX(d)	2.82			2.70			2.53			2.98			2.72			3.04			3.34			2.99		
DOMINANCE INDEX(s)	0.19			0.24			0.26			0.16			0.21			0.18			0.12			0.16		

APPENDIX 18 - Benthic macro-invertebrates collected from the Athabasca River - September 14 - 15, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA				12	6	12	3		6						1					2	9			
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.																								
Siphlonurus sp.																								
Isonychia sp.							2						1											
Baetidae																								
Baetis dardanus			1																					
Baetis tricaudatus		1				3	3	1	2	1			2	8	5	1	1		1	1	1	2	4	3
Centroptilum rivulare								1	4						1									
Pseudocloeon sp.																								
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata	3	9	14	6	11	22	3	3	12	10	3	3	9	1	1	1	3	2		2				
Heptagenia diabasia						3																		
Heptagenia elegantula																								
Heptagenia pulla	8	16	16	60	85	86	50	17	101	35	16	15	16	26	32	10	22	13	12	22	18	43	4	13
Nixe simplicoides																								
Rhithrogena undulata	18	34	1	31	17	4	6	7	21	14	12	26	80	117	40	3	11	7	22	26	35	194	146	65
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei								1	3										3	1	1			
Metretopus borealis						4				2														
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.							1																	
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis		1		1		1	3			8	2	1	2	4	3		2	1	2	4	1	16	16	2
Tricorythidae																								
Tricorythodes minutus									1			1				1						2		
Caenidae																								
Caenis tardata																								
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.				10	8	10	31	2	14	24	12	13	13	9	18	10	6	10	2	3	1	4	4	2
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata			1				1				1	1	1	1	1	3	2		3	3	1			2
Nemouridae																								
Nemoura sp.										1														
Chloroperlidae																								
Hastaperla brevis										1			1						1			1	1	1
Triznaka signata																								
Perlidae																								
Classenia sabulosa						1																		
Acroneuria abnormis										1														
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	22	32	20	11	13	13	66	36	35	47	55	49	60	48	40	2	9	10	34	28	49	32	41	49
Isoperla longiseta																								
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.																3	1						1	
Cheumatopsyche spp.	187	411	146	256	215	193	409	253	298	468	810	378	251	249	172	199	168	171	132	139	203	55	69	108
Hydropsyche spp.	74	78	51	13	1	2	28	5	12	51	87	21	53	12	4	16	38	20	8	21	17	120	171	195
Glossomatidae																								
Glossoma sp.										3	1		2										1	
Brachycentridae																								
Brachycentrus sp.	1		1			1	3	1	2	9	4	3	1	1	1	4	7	4	13	6	20	7	14	13
Leptoceridae																								
Triaenodes sp.				1		1	1	1	1										1					
DIPTERA																								
Ceratopogonidae																			1					
Chironomidae	5	4	1	10	16	14	13	1	5	3			2	3	6	6	6	29	4	10	11	5	3	2
Empididae																								
Hemerodromia sp.	8	3	3		1		7		2	3	1	10	2		3	10	21	40	2	8	3	8	2	25
Rhagionidae																								
Atherix sp.			1																					
Simuliidae																								
Simulium arcticum																								
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	326	589	256	411	373	370	630	329	519	681	1004	521	496	479	328	269	297	307	241	276	370	489	477	480
TOTAL INVERTEBRATES		1171			1154			1478			2206			1303			873			887		1446	
COEFF. OF VARIATION(%)		45.0			5.9			30.9			33.5			21.3			6.8			22.6		1.3	
NO. OF TAXA	9	10	12	11	10	16	17	13	16	17	12	12	16	12	15	14	14	11	16	15	14	13	14	13
TOTAL TAXA		14			17			20			19			18			15			18		16	
DIVERSITY INDEX(d)		1.79			2.10			1.95			1.51			2.27			2.15			2.43		2.55	
DOMINANCE INDEX(s)		0.44			0.38			0.45			0.58			0.32			0.40			0.32		0.23	

APPENDIX 19 - Benthic macro-invertebrates collected from the Athabasca River - September 21, 1983

Site Location	-20			40			80			120			160			180			200			240		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
OLIGOCHAETA				1															6	7	1			
INSECTA																								
EPHEMEROPTERA																								
Siphlonuridae																								
Ameletus sp.	2					2				1		1		1								1	1	
Siphlonurus sp.																								
Isonychia sp.																								
Baetidae																								
Baetis dardanus																								
Baetis tricaudatus			1		1	2		2	2	3		2	2		1	2						7		6
Centroptilum rivulare		3		6		2		1	1		1													
Pseudocleon sp.																								
Heptageniidae																								
Epeorus ironodes																								
Epeorus vitrea																								
Heptagenia adequata	8	13	3	36	46	42	3	3	1	43	17	16	7	6	13				16	14	28	4	20	2
Heptagenia diabasia		2					1	1	2	2			1	1									3	
Heptagenia elegantula								1	1															
Heptagenia pulla	15	9	6	167	125	215	53	124	133	73	67	44	94	41	30	5	1	4	40	59	50	44	89	37
Nixe simplicoides																								
Rhithrogena undulata	8	3	2	40	35	29	29	19	31	3	5	1	1	5	2		1		20	40	7	164	95	162
Stenonema terminatum																								
Ametropodidae																								
Ametropus neavei					1			1		3	9	6							3	1	1		1	
Metretopus borealis					10	15					1	1							2	1	1			
Siphloplecton sp.																								
Leptophlebiidae																								
Leptophlebia sp.								1	1	1		1												
Paraleptophlebia sp.																								
Ephemerellidae																								
Ephemerella inermis					2	2	8	5	4	4	7	3	14	3	2				12	28	12	53	11	15
Tricorythidae																								
Tricorythodes minutus				1	1	1	1		2	2	1	1		1					2	1			1	
Caenidae																								
Caenis tardata															1									
Ephemeridae																								
Hexagenia sp.																								
ODONATA																								
Gomphidae																								
Ophiogomphus sp.				5	5	7	7	5	4	29	30	33	16	15	20	3	3	6	6	4	6	1	8	2
PLECOPTERA																								
Pteronarcidae																								
Pteronarcys dorsata										2	2			1			1		1	1		3	1	5
Nemouridae																								
Nemoura sp.																								
Chloroperlidae																								
Hastaperla brevis												1			1				1	1		3		
Triznaka signata																								
Perlidae																								
Classenia sabulosa																								
Acroneuria abnormis					1																			
Perlodidae																								
Arcynopteryx sp.																								
Skwala sp.																								
Isogenoides sp.	23	10	16	22	13	13	41	56	75	19	14	11	8	7	6	6	5	4	25	46	10	118	25	95
Isoperla longiseta																								
TRICHOPTERA																								
Hydropsychidae																								
Arctopsyche sp.														1										
Cheumatopsyche spp.	130	29	84	160	41	73	94	160	120	26	74	96	45	85	83	54	29	31	29	14	21	5	8	16
Hydropsyche spp.	38	1	26	2	1	1	1	4	4		1	2	1	2	5	17	13	4	2	4	1	31	7	100
Glossomatidae																								
Glossoma sp.						1						1		1										
Brachycentridae																								
Brachycentrus sp.	3			1		1					1	1	4	2	1	6	3	3	2	11	12	40	12	20
Leptoceridae																								
Triaenodes sp.							1																	
DIPTERA																								
Ceratopogonidae																								
Chironomidae	14	7	1	14	12	65	4	8	2	9	11	5	36	7	32	14	3	13	22	11	11	2	13	4
Empididae																								
Hemerodromia sp.	7	1	4				1	2	3	38	25	9	5	1	8	21	1	23	1	1	5	6	2	16
Rhagionidae																								
Atherix sp.									2														2	3
Simuliidae																								
Simulium arcticum																								
Tipulidae																								
COLEOPTERA																								
Elmidae																								
NO. OF INVERTEBRATES	248	78	143	455	294	471	244	393	388	258	266	235	234	180	205	128	60	88	190	244	166	482	299	483
TOTAL INVERTEBRATES		469			1220			1025			759			619			276			600			1264	
COEFF. OF VARIATION(%)		54.9			24.1			24.8			6.4			13.1			37.2			20.0			25.1	
NO. OF TAXA	10	10	9	12	14	16	13	16	17	16	16	19	13	17	14	9	10	8	17	17	14	15	17	14
TOTAL TAXA		13			19			19			22			20			11			17			19	
DIVERSITY INDEX(d)		2.37			2.52			2.38			3.04			2.74			2.58			3.30			2.93	
DOMINANCE INDEX(s)		0.31			0.25			0.26			0.16			0.22			0.23			0.13			0.19	

Appendix 20 - Invertebrate and vertebrate organisms collected in four hour drift net samples from 178 km site on Athabasca River, May 31, 1983

Sampling period	0400			0800			1200			1600			2000			2400		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																		
EPHEMEROPTERA																		
Siphlonuridae																		
Ameletus sp.																		
Parameletus columbiae																	1	
Baetidae																		
Baetis dardanus																		
Baetis tricaudatus							1							1	4	22	12	7
Heptageniidae																		
Epeorus ironodes																		
Heptagenia adequata													1				8	8
Heptagenia diabasia																		
Heptagenia pulla														2		14	12	23
Pseudiron sp.							1											
Rhithrogena undulata									1				1	4	5	64	50	26
Ametropodidae																		
Ametropus neavei																		
Metrotopus borealis																46	9	40
Siphloplecton sp.																		
Ephemerellidae																		
Ephemerella inermis														1		12	4	2
Tricorythidae																		
Tricorythodes minutus																		
Ephemeridae																		
Hexagenia limbata																		
PLECOPTERA																		
Pteronarcidae																		
Pteronarcys dorsata																	1	
Chloroperlidae																		
Hastaperla brevis								5	2				2	2	2	46	24	64
Perlidae																		
Classenia sabulosa																4	2	
Acroneuria abnormis																		
Perlodidae																		
Isogenoides sp.							6	22	5				18	21	46	182	106	168
Isoperla longiseta							2	2	8				5	18	17	128	170	168
TRICHOPTERA																		
Hydropsychidae																		
Arctopsyche sp.																		
Cheumatopsyche spp.																		
Hydropsyche spp.																	2	6
Glossomatidae																		
Glossoma sp.																2	1	8
Brachycentridae																		
Brachycentrus sp.																		
Leptoceridae																		
DIPTERA																		
Ceratopogonidae																		
Chironomidae														1		5	1	
Simuliidae																		
Simulium arcticum								5	3						1		1	
Tipulidae																		
COLEOPTERA																		
OSTEICHTHYES																		
Fish Fry *spp.*																		
NO. OF ORGANISMS							10	34	19	0	0	0	27	50	75	525	404	520
TOTAL ORGANISMS								63			0			152			1449	
COEFF. OF VARIATION(%)								57.6						47.3			14.2	
NO. OF TAXA							4	4	5	0	0	0	5	8	6	11	16	11
TOTAL TAXA								8			0			9			16	
DIVERSITY INDEX(d)								1.96						1.85			2.75	
DOMINANCE INDEX(s)								0.34						0.39			0.23	

Appendix 20 - Invertebrate and vertebrate organisms collected in four hour drift net samples from 178 km site on Athabasca River, June 1, 1983

Sampling period	0400			0800			1200			1600			2000			2400		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																		
EPHEMEROPTERA																		
Siphlonuridae																		
Ameletus sp.		1			1	2												
Parameletus columbiae			3	1		1												
Baetidae																		
Baetis dardanus																		
Baetis tricaudatus	5	4	4	3	5	1							1					
Heptageniidae																		
Epeorus ironodes																		
Heptagenia adequata	8	5	8						1									
Heptagenia diabasia																		
Heptagenia pulla	2	2	4			1												
Pseudiron sp.	1	2	2															
Rhithrogena undulata	36	29	18	10	5	4	1							2	1			
Ametropodidae																		
Ametropus neavei																		
Metrotopus borealis																		
Siphloplecton sp.	4	7	4															
Ephemerellidae																		
Ephemerella inermis	16	18	19	5	2	3										1	2	
Tricorythidae																		
Tricorythodes minutus																		
Ephemeridae																		
Hexagenia limbata																		
PLECOPTERA																		
Pteronarcidae																		
Pteronarcys dorsata		1			1													
Chloroperlidae																		
Hastaperla brevis	16	13	11		3	8		1	2					1				
Perlidae																		
Classenia sabulosa		1																
Acroneuria abnormis																		
Perlodidae																		
Isogenoides sp.	74	74	49	4	9	25	2	3	7	2	2	1		1	3		1	
Isoperla longiseta	26	16	6	3	1	6		1	1									
TRICHOPTERA																		
Hydropsychidae																		
Arctopsyche sp.																		
Cheumatopsyche spp.	5	4	4	1	1	3		1	1									
Hydropsyche spp.	3	1	1		1	2												
Glossomatidae																		
Glossoma sp.	1		1	1				2	1					1				
Brachycentridae																		
Brachycentrus sp.																		
Leptoceridae																		
DIPTERA																		
Ceratopogonidae																		
Chironomidae	1	1	2	1	7	2			1		1		1					2
Simuliidae																		
Simulium arcticum				1	2								1					
Tipulidae																		
COLEOPTERA																		
OSTEICHTHYES																		
Fish Fry *spp.*													2	1	5			
NO. OF ORGANISMS	198	179	136	30	38	58	3	8	14	2	3	2	4	6	9	1	3	2
TOTAL ORGANISMS	513			126			25			7			19			6		
COEFF. OF VARIATION(%)	18.6			34.3			66.3			25.2			39.7			50.0		
NO. OF TAXA	14	16	15	10	12	12	2	5	7	1	2	2	3	5	3	1	2	1
TOTAL TAXA	18			15			8			3			7			3		
DIVERSITY INDEX(d)	2.92			3.22			2.38			1.15			2.31			1.46		
DOMINANCE INDEX(s)	0.21			0.15			0.32			0.54			0.26			0.39		

Appendix 20 - Invertebrate and vertebrate organisms collected in four hour drift net samples from 178 km site on Athabasca River, June 2, 1983

Sampling period	0400			0800			1200			1600			2000			2400		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																		
EPHEMEROPTERA																		
Siphlonuridae																		
Ameletus sp.																		
Parameletus columbiae																		
Baetidae																		
Baetis dardanus																		
Baetis tricaudatus																		
Heptageniidae																		
Epeorus ironodes																		
Heptagenia adequata		1																
Heptagenia diabasia																		
Heptagenia pulla				1														
Pseudiron sp.																		
Rhithrogena undulata	1																	
Ametropodidae																		
Ametropus neavei																		
Metrotopus borealis																		
Siphloplecton sp.																		
Ephemerellidae																		
Ephemerella inermis	10	19	11	2	2	1												
Tricorythidae																		
Tricorythodes minutus																		
Ephemeridae																		
Hexagenia limbata																		
PLECOPTERA																		
Pteronarcidae																		
Pteronarcys dorsata																		
Chloroperlidae																		
Hastaperla brevis																		
Perlidae																		
Classenia sabulosa																		
Acroneuria abnormis																		
Perlodidae																		
Isogenoides sp.	2	3			1													
Isoperla longiseta																		
TRICHOPTERA																		
Hydropsychidae																		
Arctopsyche sp.																		
Cheumatopsyche spp.	1	1	2															
Hydropsyche spp.																		
Glossomatidae																		
Glossoma sp.																		
Brachycentridae																		
Brachycentrus sp.																		
Leptoceridae																		
DIPTERA																		
Ceratopogonidae																		
Chironomidae	3	1	1	1			1											
Simuliidae																		
Simulium arcticum																		
Tipulidae																		
COLEOPTERA																		
OSTEICHTHYES																		
Fish Fry *spp.*																		
NO. OF ORGANISMS	18	25	14	4	3	2												
TOTAL ORGANISMS		57			9													
COEFF. OF VARIATION(%)		29.5			33.3													
NO. OF TAXA	6	5	3	3	2	2												
TOTAL TAXA		7			4													
DIVERSITY INDEX(d)		1.55			1.66													
DOMINANCE INDEX(s)		0.51			0.39													

Appendix 21 - Invertebrate and vertebrate organisms collected in four hour drift 'bomb' samples from 178 km site on Athabasca River, May 31, 1983

Sampling period	0400			0800			1200			1600			2000			2400		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																		
EPHEMEROPTERA																		
Siphlonuridae																		
Ameletus sp.																		
Parameletus columbiae																8		3
Baetidae																		
Baetis dardanus																		
Baetis tricaudatus													256	192	320	272	88	160
Heptageniidae																		
Epeorus ironodes													96	16	120	32	1	16
Heptagenia adequata													26	10	30	48	4	18
Heptagenia diabasia																4		
Heptagenia pulla													60	60	70	132	16	192
Pseudiron sp.												1						
Rhithrogena undulata											1		2064	1040	2374	1572	196	1744
Ametropodidae																		
Ametropus neavei													16	64	19		2	
Metrotopus borealis																		
Siphloplecton sp.																	2	
Ephemerellidae																		
Ephemerella inermis													32	48	40			6
Tricorythidae																		
Tricorythodes minutus																		
Ephemeridae																		
Hexagenia limbata																		
PLECOPTERA																		
Pteronarcidae																		
Pteronarcys dorsata													170	80	196	80	8	12
Chloroperlidae																		
Hastaperla brevis										5	5	9	2368	1088	2724	1076	52	656
Perlidae																		
Classenia sabulosa													16	12	14	12	4	16
Acroneuria abnormis															3			
Perlodidae																		
Isogenoides sp.										19	12	30	8000	3392	9200	2990	360	1808
Isoperla longiseta										10	10	22	1500	512	1725	448	20	192
TRICHOPTERA																		
Hydropsychidae																		
Arctopsyche sp.																		
Cheumatopsyche spp.											1		128	48	160	128	24	48
Hydropsyche spp.										1			16	32	45	112	52	128
Glossomatidae																		
Glossoma sp.													64	112	95	96		80
Brachycentridae																		
Brachycentrus sp.																	1	
Leptoceridae																		
DIPTERA																		
Ceratopogonidae																		
Chironomidae																		
Simuliidae										1			160	128	210	160	28	64
Simulium arcticum																		
Tipulidae										5	1	5	272	320	325	112	20	96
COLEOPTERA																		
OSTEICHTHYES																		
Fish Fry *spp.*																		
NO. OF ORGANISMS										41	30	67	15244	7154	17670	7282	878	5239
TOTAL ORGANISMS											138			40068			13399	
COEFF. OF VARIATION(%)											41.3			82.2			73.2	
NO. OF TAXA										6	6	5	17	17	18	17	17	17
TOTAL TAXA											9			19			21	
DIVERSITY INDEX(d)											1.99			2.28			2.64	
DOMINANCE INDEX(s)											0.31			0.32			0.24	

Appendix 21 - Invertebrate and vertebrate organisms collected in four hour drift 'bomb' samples from 178 km site on Athabasca River, June 1, 1983

Sampling period	0400			0800			1200			1600			2000			2400		
Sample no. / TAXA	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																		
EPHEMEROPTERA																		
Siphlonuridae																		
Ameletus sp.																		
Parameletus columbiae		1	1															
Baetidae																		
Baetis dardanus																		
Baetis tricaudatus	3	2	23	12	3	7	3	1	7	2			2			1		
Heptageniidae																		
Epeorus ironodes																		
Heptagenia adequata	4			1														
Heptagenia diabasia																		
Heptagenia pulla		3	13	3	2	1		1										
Pseudiron sp.											1	1			2			
Rhithrogena undulata	234	19	83	34	13	19	17	8	8	4	2	5	2		3	3	1	2
Ametropodidae																		
Ametropus neavei	1		1															
Metrotopus borealis																		
Siphloplecton sp.																	1	
Ephemerellidae																		
Ephemerella inermis	3	2			1			1			1			1		1		1
Tricorythidae																		
Tricorythodes minutus																		
Ephemeridae																		
Hexagenia limbata																		
PLECOPTERA																		
Pteronarcidae																		
Pteronarcys dorsata	1	2	1	2														
Chloroperlidae																		
Hastaperla brevis	12	4		3	4	4	3	1	2	2								2
Perlidae																		
Classenia sabulosa	1		1	1														
Acroneuria abnormis																		
Perlodidae																		
Isogenoides sp.	176	22	74	68	20	36	29	10	14	11	1	9	8	4	6	4	5	1
Isoperla longiseta	15	2		5	2	2	2		2	1			1	1				1
TRICHOPTERA																		
Hydropsychidae																		
Arctopsyche sp.																		
Cheumatopsyche spp.			7	5	1	3	4		2	1			1		1			
Hydropsyche spp.	41	12	60	9	3	7	6	5	2	1	1	1	1	1		1		
Glossomatidae																		
Glossoma sp.	16	1	3	3	9	4	6		6	2	1	3		1	4			3
Brachycentridae																		
Brachycentrus sp.																		
Leptoceridae																		
DIPTERA																		
Ceratopogonidae																		
Chironomidae	1			3		2	2	1	3	5	1	2	1		2	1		
Simuliidae																		
Simulium arcticum	3			2	1	3				1		1					1	1
Tipulidae																		
COLEOPTERA																		
OSTEICHTHYES																		
Fish Fry *spp.*									1									
NO. OF ORGANISMS	511	70	283	151	59	88	72	28	47	30	8	22	16	8	18	11	8	11
TOTAL ORGANISMS	864			298			147			60			42			30		
COEFF. OF VARIATION(%)	76.6			47.3			45.1			55.5			37.8			17.3		
NO. OF TAXA	14	11	12	14	11	11	9	8	10	10	7	7	7	5	6	5	4	7
TOTAL TAXA	17			14			12			12			10			11		
DIVERSITY INDEX(d)	2.38			2.69			2.75			2.87			2.71			2.92		
DOMINANCE INDEX(s)	0.27			0.24			0.21			0.22			0.27			0.18		

Appendix 21 - Invertebrate and vertebrate organisms collected in four hour drift 'bomb' samples from 178 km site on Athabasca River, June 2, 1983

Sampling period	0400			0800			1200			1600			2000			2400		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																		
EPHEMEROPTERA																		
Siphlonuridae																		
Ameletus sp.																		
Parameletus columbiae																		
Baetidae																		
Baetis dardanus																		
Baetis tricaudatus																		
Heptageniidae																		
Epeorus ironodes																		
Heptagenia adequata																		
Heptagenia diabasia																		
Heptagenia pulla																		
Pseudiron sp.						2												
Rhithrogena undulata	3		4			1												
Ametropodidae																		
Ametropus neavei																		
Metrotopus borealis																		
Siphloplecton sp.																		
Ephemerellidae																		
Ephemerella inermis		2	9			1												
Tricorythidae																		
Tricorythodes minutus																		
Ephemeridae																		
Hexagenia limbata																		
PLECOPTERA																		
Pteronarcidae																		
Pteronarcys dorsata	1																	
Chloroperlidae																		
Hastaperla brevis	1		2			2												
Perlidae																		
Classenia sabulosa																		
Acroneuria abnormis																		
Perlodidae																		
Isogenoides sp.	2	4	3	1		9												
Isoperla longiseta	1		1															
TRICHOPTERA																		
Hydropsychidae																		
Arctopsyche sp.																		
Cheumatopsyche spp.																		
Hydropsyche spp.			1			1												
Glossomatidae																		
Glossoma sp.	1		2	3														
Brachycentridae																		
Brachycentrus sp.																		
Leptoceridae																		
DIPTERA																		
Ceratopogonidae																		
Chironomidae		1																
Simuliidae																		
Simulium arcticum		3		1		1												
Tipulidae																		
COLEOPTERA																		
OSTEICHTHYES																		
Fish Fry *spp.*																		
NO. OF ORGANISMS	9	10	23	5	0	17												
TOTAL ORGANISMS		42			22													
COEFF. OF VARIATION(%)		55.7			119.2													
NO. OF TAXA	6	4	7	3	0	7												
TOTAL TAXA		10			8													
DIVERSITY INDEX(d)		2.90			2.46													
DOMINANCE INDEX(s)		0.16			0.26													

Appendix 22 - Invertebrate and vertebrate organisms collected in four hour drift net samples from 178 km site on Athabasca River, July 6, 1983

Sampling period	0400			0800			1200			1600			2000			2400		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																		
EPHEMEROPTERA																		
Siphlonuridae																		
Ameletus sp.																		
Parameletus columbiae																		
Baetidae																		
Baetis dardanus	8		1	1	7	5	112	8	132	50	51	35	2	2	2	3	8	14
Baetis tricaudatus	2			3	4	11	132	2	56	3	4	2					2	
Heptageniidae																		
Epeorus ironodes				1			44	2	24		3	1						
Heptagenia adequata	2	1		3		1	24		20	4	4	12	1	1	1			
Heptagenia diabasia	6	5	1	3	1	2	40	24	8	38	30	23	2	2	1	1	7	10
Heptagenia pulla							52		44	12	20	4			1			
Pseudiron sp.																		
Rhithrogena undulata									4	2	1	2						
Ametropodidae																		
Ametropus neavei																		
Metrotopus borealis																		1
Siphloplecton sp.							4			2		1						
Ephemerellidae																		
Ephemerella inermis		2		2		1	4				2	1				1		
Tricorythidae																		
Tricorythodes minutus																		
Ephemeridae																		
Hexagenia limbata																		
PLECOPTERA																		
Pteronarcidae																		
Pteronarcys dorsata										1								
Chloroperlidae																		
Hastaperla brevis							6		20	1	1							
Perlidae																		
Classenia sabulosa																		
Acroneuria abnormis																		
Perlodidae																		
Isogenoides sp.				1			356	16	252	61	69	57		1		6	1	2
Isoperla longiseta	6	1	6	3	1		84	3	32	8	9	8				1		
TRICHOPTERA																		
Hydropsychidae																		
Arctopsyche sp.																		
Cheumatopsyche spp.		1																
Hydropsyche spp.							57		59	54	44	34				1	2	2
Glossomatidae																		
Glossoma sp.																		
Brachycentridae																		
Brachycentrus sp.							1											
Leptoceridae							1											
DIPTERA																		
Ceratopogonidae						1	1											
Chironomidae									4	2	1	1						1
Simuliidae																		
Simulium arcticum									5			1					1	
Tipulidae																		
COLEOPTERA																		
OSTEICHTHYES																		
Fish Fry *spp.*																	1	
NO. OF ORGANISMS	26	10	8	17	13	21	922	55	660	238	239	182	5	6	5	13	21	31
TOTAL ORGANISMS		44			51			1637			659			16			65	
COEFF. OF VARIATION(%)		67.3			23.5			81.5			14.8			10.9			41.5	
NO. OF TAXA	6	5	3	8	4	6	16	6	13	13	13	14	3	4	4	6	6	7
TOTAL TAXA	6	5	3		9			19			16			4			11	
DIVERSITY INDEX(d)		2.50			2.55			2.83			2.74			2.01			2.43	
DOMINANCE INDEX(s)		0.22			0.22			0.20			0.19			0.28			0.25	

Appendix 23 - Invertebrate and vertebrate organisms collected in four hour drift 'bomb' samples from 178 km site on Athabasca River, July 6, 1983

Sampling period	0400			0800			1200			1600			2000			2400		
TAXA / Sample no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
INSECTA																		
EPHEMEROPTERA																		
Siphlonuridae																		
Ameletus sp.																		
Parameletus columbiae									4									
Baetidae																		
Baetis dardanus																		
Baetis tricaudatus	1	3	1	2	2	1	52	20	4	1		5	1					
Heptageniidae																		
Epeorus ironodes	13	1		2	2	1	32	15	4	2		3			2			1
Heptagenia adequata							12	4	72	1								
Heptagenia diabasia	1							20										
Heptagenia pulla	4	2		2	1	3	310	128	20	6	10	3	2					
Pseudiron sp.																		
Rhithrogena undulata				1			60		12	2	4	1	2					
Ametropodidae																		
Ametropus neavei																		
Metrotopus borealis																		
Siphloplecton sp.																		
Ephemerellidae																		
Ephemerella inermis				1					8									
Tricorythidae																		
Tricorythodes minutus	1																	
Ephemeridae																		
Hexagenia limbata										1								
PLECOPTERA																		
Pteronarcidae																		
Pteronarcys dorsata	2						110	30	8	4	6		1					
Chloroperlidae																		
Hastaperla brevis	1			1			20				2	1						
Perlidae																		
Classenia sabulosa																		
Acroneuria abnormis																		
Perlodidae																		
Isogenoides sp.	12		3	35		3	1056	480	176	82	164	21	24	8	9	1		6
Isoperla longiseta	21	1		47	16	4	960	560	312	52	70	6	4	2	2			
TRICHOPTERA																		
Hydropsychidae																		
Arctopsyche sp.									8									
Cheumatopsyche spp.	1			1														
Hydropsyche spp.	43	10		163	13	10	4600	2625	1036	268	512	69	45	6	11	5		10
Glossomatidae																		
Glossoma sp.							16			2	8		1					
Brachycentridae																		
Brachycentrus sp.				1														1
Leptoceridae																		
DIPTERA																		
Ceratopogonidae						1							1					
Chironomidae	13	1		3	1	5	32	80	4	15	8	4	9	1	1			1
Simuliidae																		
Simulium arcticum	12	1	1	6	5	7	98	70	12	4	8		4	1	1			3
Tipulidae	1			1														
COLEOPTERA							1											
OSTEICHTHYES																		
Fish Fry *spp.*																		
NO. OF ORGANISMS	126	19	5	266	38	35	7359	4032	1680	440	792	113	94	18	25	6	0	22
TOTAL ORGANISMS	150			339			13,071			1345			137			28		
COEFF. OF VARIATION(%)	132.4			117.3			65.5			75.8			91.9			122.6		
NO. OF TAXA	14	7	3	14	6	9	14	11	14	13	10	9	11	5	6	2	0	6
TOTAL TAXA	14			15			18			14			12			6		
DIVERSITY INDEX(d)	2.90			2.08			1.82			1.73			2.20			1.84		
DOMINANCE INDEX(s)	0.18			0.39			0.44			0.45			0.31			0.36		

N.L.C. - B.N.C.
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